The DENTAL JOURNAL OF Australia

AUSTRALIAN DENTAL ASSOCIATION N.S.W. BRANCH

VOLUME - - 33
NUMBER - - 1
MARCH - 1988

The DENTAL Journal OF AUSTRALIA

Vol. 22 March, 1950 No. 3

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Editor: ROBERT HARRIS, M.D.S.

Published by the Australian Dental Association (N.S.W. Branch)
B.M.A. HOUSE, 135-137 MACQUARIE STREET, SYDNEY

Communications intended for publication in "The Dental Journal of Australia" should be addressed to the Editor. All advertising and business matters should be directed to the Secretary.

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The DENTAL Journal OF AUSTRALIA

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THE HYGROSCOPIC EXPANSION TECHNIQUE IN DENTAL CASTING.

PART 4

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and

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INTRODUCTION.

The influence of composition and technique on the setting expansion of experimental casting investments when immersed in water soon after mixing has already been studied and discussed[1]. Most of the hygroscopic setting experiments then described were conducted with the freshly-mixed investment floating freely on mercury except for an attachment at one end[2].

It was emphasised that caution was necessary in applying the data obtained to investments in the confines of an inlay ring; for instance, as Brumfield[3] has shown from mechanical and mathematical considerations, a maximum lateral setting expansion of the order of 0.03 per cent. is the most that can be expected from an unlined metal ring. Investigations on investments used under such conditions would clearly be of little value. It was considered desirable, however, to study the effects of hygroscopic expansion on investment moulds within asbestos-lined rings. This paper describes several approaches to the problem.

In the first instance, attempts were made to measure directly at least the longitudinal expansion of investments in inlay rings. Second, small rectangular blocks were cast in gold from dimensioned wax patterns, and following this experiment MOD shaped castings and then inlays for cavities prepared in extracted teeth were cast and tested for accuracy of fit. Finally, comments were sought from practitioners using hygroscopic expansion technique, some of whom co-operated in the preparation of experimental castings.

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[1]Docking, A. R., Donnison, Joan A., and Chong, M.P.—The Hygroscopic Expansion Technique in Dental Casting, Part 3. D.J.A. 21: 63-80 (1949).

[2]Docking, A. R., Chong, M.P., and Donnison, Joan A.—The Hygroscopic Expansion Technique in Dental Casting, Part 2. D.J.A. 20: 320-32 (1948).

[3]Brumfield, R. C.—Private Communication.

Expansion in the Inlay Ring.

A knowledge of the dimensional changes taking place in a lined inlay ring would be of value. No comprehensive attempt was made to gain this information but a few special tests were devised using a refinement of a method described by Degni[1].

Apparatus and Technique.

The equipment used is shown in Figure 1. The inlay ring containing the specimen stands on a ring base of appropriate size supported in a "cage" which

Figure 1.—Apparatus for ring tests. Two types of needle, one mounted on the investment, and the ring base are shown in the foreground.

is constructed of invar to minimise errors due to the thermal expansion of the supports when immersed in warm water.

Before pouring the investment the selected inlay ring is sealed into its base with wax and the liner placed in position. When wet asbestos is used the liner is saturated with water just prior to filling the ring and excess water shaken off gently. It was found by this means that the amount of water in the liner could be kept fairly constant. Unless otherwise stated, wet asbestos was used as a liner throughout the experiments described in this part of the series.

The investment is mixed in the normal way and the ring filled level with the top. A needle set on a small acrylic base is then placed on the upper surface of the specimen and the ring set in position on the base of the cage. Dimensions of the ring are designed to give an investment specimen 50 mm. in length.

[1]Degni, F.—"Study of Hygroscopic Setting Expansion of Dental Investments." Thesis, Northwestern University Dental School (1946). (Typescript.)

The vertical movement of the needle is observed and measured to the nearest 0.01 mm. by means of a cathetometer as shown in Figure 2. For hygroscopic setting tests the container filled with water at the appropriate

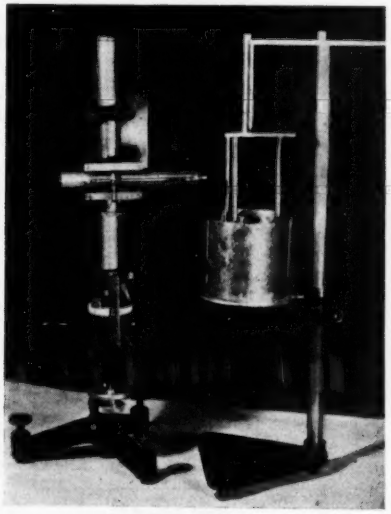

Figure 2.—The apparatus arranged for hygroscopic setting expansion tests. The crosswire in the eyepiece of the cathetometer on the left is registered on the point of the needle.

temperature is raised so that the ring becomes completely immersed, as may be seen by comparing the two photographs. The whole equipment is held on a solid bench designed to eliminate vibration.

RESULTS AND DISCUSSION.

On plotting expansion, as indicated by the vertical movement of the needle, against time after commencement of mixing, a series of curves was obtained. It wil be seen from Figures 3 and 4 that the form of these curves is very similar to that characteristic of the mercury trough experiments [1]. As expected the ring results are much lower than those obtained with the mercury trough, for in the latter the expansion is almost unrestricted. On the other hand "normal" setting expansions obtained in the lined ring are higher than the corresponding results on the mercury bath, obviously due to the use of a wet asbestos liner in the ring. When a dry asbestos liner is used the expansion results obtained by the two methods are in somewhat closer agreement.

When an unlined, but slightly greased ring is used, the setting expansions, whether normal or hygroscopic, are consistently low, never rising above 0.25 per cent. in the experiments carried out (compare Table 2). Similar effects were reported by Watts[5] who was able to measure the lateral expansion in the ring by observing the relative movement of two markers placed in the surface

[5]Watts, C. H.—A Study of Investment Expansions Required for Gold Inlay Castings. Paper read before the Materials Group, I.A.D.R. Dated March 16, 1946. (Microfilm.)

of the investment. These results demonstrate the futility of using an unlined ring when expansion of the investment is desired. It is necessary, moreover, for the liner to be fairly loosely packed to allow full expansion.

Care must be taken in interpreting the results obtained while the mixed investment is still in a semi-fluid state. In the first place it is possible that, in a system partly restrained in two directions and free to move in a third, more than one-third of the volume expansion will be directed to the free direction, giving results that are too high. Again, in previous papers it was stressed that with the type of curve shown in Figures 3 and 4, where readings com-

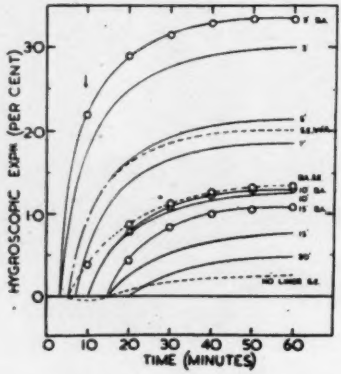

Figure 3.—Hygroscopic setting expansion of Investo Superfine Investment in the ring. Water-investment ratio: 0.35. All times shown are taken from the time of commencement of mixing. Immersing times are shown at end of curves. Wet asbestos: W.A. Dry asbestos: D.A. Setting expansion: S.E. (broken curves). Arrow indicates Gillmore initial setting time.

menced as early as three minutes after commencement of the mix, it is necessary to bear in mind the fact that at such an early stage the expansion has no practical meaning. It is not until some point or range is reached that the expansion commences to become effective. In the absence of a better

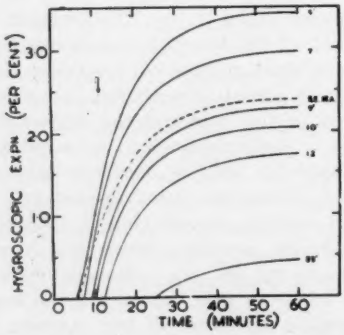

Figure 4.—Hygroscopic setting expansion of Calsite Inlay Investments in the ring. Water-investment ratio: 0.38. Wet Asbestos: W.A. Setting expansion: S. E. broken curve. Arrow indicates Gillmore initial setting time.

criterion the Gillmore initial setting time may be taken. When this is done the recalculated results for "effective" expansion obtained from the ring experiments are found to agree fairly well with those computed in the same way from the mercury bath experiments.

It is instructive to compare the expansions calculated in several ways. The best example was that of Alston Investment Compound (The Dental Manufacturing Co. Ltd., London). In Table 1 the expansions up to 60 minutes, at which time the expansion rate becomes very small, have been calculated from the time of immersion of the ring in water, from the Gillmore setting time, and from five minutes respectively, the last results including the "normal" setting expansion (with a wet asbestos liner) that has taken place between five minutes and the time of immersion. In other words, the figures in the fourth column represent total expansion. It is obvious that with the Alston Investment sample nothing is to be gained at any time by immersing the ring in water if a wet asbestos liner is used.

TABLE 1
Hygroscopic Setting Expansion of Alston Investment Compound.
(W/I ratio 0.50; Gillmore setting time, 14¼ minutes).

Time interval between mixing and immersion	Expansion, from immersion time to 60 minutes	Effective Expansion (from 14¼ to 60 minutes)	Total Expansion (including normal setting), from 5 to 60 minutes
minutes	per cent.	per cent.	per cent.
5	1.62	0.56	1.62
7	1.39	0.54	1.67
9	1.14	0.58	1.73
10	0.78	0.45	1.50
15	0.54	0.54	1.73
No immersion (wet asbestos only)		0.57	1.71

Tables 2 and 3 have been computed in a similar manner for Investo Superfine and Calsite Inlay Investments respectively.

TABLE 2
Hygroscopic Setting Expansion of Investo Superfine Investment.
(W/I ratio 0.35; Gillmore setting time, 9½ minutes).

Liner	Time interval between mixing and immersion	Expansion, from immersion time to 60 minutes	Effective Expansion (from 9½ to 60 minutes)	Total Expansion (including normal setting), from 5 to 60 minutes
	minutes	per cent.	per cent.	per cent.
Wet asbestos	3	3.00	1.34	(2.40)
" "	5	2.15	1.25	2.15
" "	7	1.88	1.35	2.37
" "	10	1.26	1.26	2.22
" "	15	0.78	0.78+	2.16
" "	20	0.50	0.50+	2.11
" "	No immersion		1.10	1.99
Dry asbestos	3	3.38	1.20	(2.70)
" "	10	1.32	1.31	1.71
" "	15	1.20	1.10+	1.89
" "	No immersion		0.45	1.35
No liner	No immersion		0.28	0.24

TABLE 3

Hygroscopic Setting Expansion of Calsite Inlay Investment.
(W/I ratio 0.38; Gillmore setting time, 11½ minutes).

Time interval between mixing and immersion	Expansion, from immersion time to 60 minutes	Effective Expansion (from 11½ to 60 minutes)	Total Expansion (including normal setting), from 5 to 60 minutes
minutes	per cent.	per cent.	per cent.
5	3.43	2.13	3.43
7	2.94	1.95	3.14
9	2.31	1.80	2.94
10	2.00	1.76	2.78
12	1.82	1.74+	2.88
25	0.44	.44+	2.42
No immersion (wet asbestos only)		1.53	2.40

In both instances, and especially in the latter, there is evidence of a gain in expansion when the hygroscopic technique is used over that obtained by the wet liner alone, particularly when the immersion is carried out at an early stage. It is also apparent that somewhat more "effective" expansion is obtained with Calsite Inlay Investment than with Investo Superfine. Both are very superior to Alston Investment Compound in this respect.

Table 2 includes some results with dry asbestos. The hygroscopic setting expansion as shown in the third column is apparently higher than the corresponding results obtained when wet asbestos is used. This is to be expected as the change from dry asbestos to immersion will be more marked than that from wet asbestos to total immersion. If the results are recalculated as in the last column it is clear that the total expansion obtained is less with dry asbestos. (The figures in the last column for three-minute immersion times were obtained by calculating the expansion from the five-minute point instead of the three-minute and do not take into account any difference in normal setting expansion.) Further, it will be noted from the fourth column that the "effective" expansions obtained after the Gillmore initial setting time are not significantly different for wet or dry asbestos.

Experiments were also carried out with Kerr Cristobalite Investment but experimental difficulties arose on account of its long Gillmore initial setting time of 30 minutes. After the addition of the freshly-mixed investment to the ring there was sufficient time for some settling to take place leaving a layer of liquid on top. The needle and support sank accordingly giving rise to

TABLE 4

Hygroscopic Setting Expansion of Kerr Cristobalite Investment.
(W/I ratio 0.38; Gillmore setting time, 30 minutes).

Time interval between mixing and immersion	Effective Expansion (from 30 to 60 minutes)
minutes	per cent.
20	0.66
23	0.69
25	0.66
No immersion (wet asbestos only)	0.58

apparent contraction and to results which were difficult to reproduce. The results summarised in Table 4 include only those from the initial setting time onwards, as these could be regarded as reliable.

These data indicate that, with Kerr Cristobalite Investment, only a little extra expansion is gained by using the hygroscopic technique in addition to the wet asbestos liner.

CONCLUSIONS.

1. Expansions in an unlined inlay ring are very low.

2. Asbestos lined rings allow a considerable expansion and there is little difference in the "effective" hygroscopic setting expansion using wet or dry asbestos.

3. Hygroscopic and normal setting expansions in the ring are lower than those obtained previously on the mercury bath, but there is little difference in the "effective" expansions obtained by the two methods.

4. The total amount of expansion, normal and hygroscopic, differs considerably from one commercial investment to another. Some investments respond to the hygroscopic technique, but in others no advantage over the use of a wet asbestos liner alone is evident.

CASTING EXPERIMENTS.

In order to determine the effect of hygroscopic expansion technique on the compensation actually achieved with gold castings, experiments were carried out on three types of casting:—

(a) Small rectangular-shaped blocks.

(b) Mesio-occlusal-distal shaped castings to fit a tapered steel die.

(c) Inlays for different types of cavity prepared in extracted teeth.

TECHNIQUE.

(a) Wax specimens approximately 12 mm. long, 4 mm. wide, and 3 mm. deep, are prepared. The ends are rounded and the whole tapered to facilitate removal from the moulds. A fine central line is scribed longitudinally on the flat upper surface of the specimen and also two parallel transverse lines spaced approximately 8 mm. apart. The distance between the transverse lines on the wax pattern is accurately measured to the nearest 0.01 mm. by means of a cathetometer. On casting, the gold specimen reproduces the fine lines and the distance between them is again measured. The dimensional difference between casting and pattern is calculated as per cent. undersize.

(b) A further step is to prepare wax patterns to fit a slightly tapered MOD steel die, similar to that used at the U.S. National Bureau of Standards[6]. The resulting fit of the gold casting subsequently obtained can then be observed and photographed.

(c) Two MOD and one proximo-occlusal type cavities were prepared in mounted extracted teeth at the Dental School, University of Melbourne, and a number of wax patterns suitably sprued taken from them.

A general casting procedure is adhered to in each instance. The wax patterns, after spruing and drawing from the die or tooth, are mounted on crucible formers with provision for a reservoir in the case of the larger castings. Before investment, the patterns are painted with a wetting agent.

[6]Coleman, R. L.—Physical Properties of Dental Materials. Bur. Stand. J. Res. 1: 867-938 (1928).

The inlay rings are lined with asbestos and placed in a dish of water so that all are saturated to approximately the same extent. Immediately after removal from the bath and shaking to remove excess water the ring is placed on the crucible former and the investment, mixed in the normal manner, is carefully vibrated around the pattern. Between 2½ and 3½ minutes after commencement of the mixing of the investment the ring and former are placed in a water bath at room temperature kept as closely as possible to 20°C. (68°F.) and left for one hour. (Apart from considerations of the softness of the wax, investing at 20°C. patterns formed at the same temperature should be equivalent to investing at 37°C. inlay patterns formed in the mouth.) The crucible former and sprue are then removed and the ring immediately placed in a controlled temperature furnace at 450°C. (840°F.) If the specimens are to be cast at this temperature the ring is left in the furnace for 1½ hours. For casting at 800°C. (1470°F.) the temperature is slowly raised to 800°C. and held at that temperature for about half an hour.

Castings are made with a centrifugal casting machine (Thermotrol), (J. F. Jelenko & Co., Inc., New York) using 20 ct. gold alloy (G.5 casting gold, Glover & Goode Pty. Ltd., Melbourne), fused at a controlled temperature of 1050°C. (1900°F.). From four to six individual tests are made in each experiment, whether block specimens or inlays, a separate mix of investment being used in each test. It will be realized, of course, that none of the investments tested, with the exception of R. & R. Hygroscopic Investment, was designed especially for use in the hygroscopic technique.

The variables studied in this way were: type of investment (commercial), water-investment ratio, effect of hygroscopic expansion, and mould temperature (either 450°C. or 800°C.). In general it was desired to compare the effectiveness of the hygroscopic expansion technique followed by casting at 450°C. with the normal technique where higher casting temperatures are used (800°C. was chosen) assuming that there are certain advantages in casting at the lower temperature.

RESULTS AND DISCUSSION.

(a) *Dimensioned Specimens.* The results for castings prepared from the dimensioned wax blocks are summarised in graphical form in Figure 5 for two local investments and in Figure 6 for certain imported investments. In these graphs the percentage discrepancy between the lines scribed on the wax pattern and the corresponding distance between the lines on the casting is plotted against the water-investment ratio. Zero discrepancy represents full compensation for casting shrinkage under the conditions of test; in other words, the farther a point is away from the axis the less the degree of compensation and the more undersized will the casting be. It will be noted that in no instance was there over-compensation, although with Kerr Cristobalite at a water-investment ratio of 0.35 exact reproduction was achieved.

An analysis of the results of these tests will indicate clearly the following points:—

(1) In so far as they can be compared there is qualitative confirmation of the results obtained from the ring tests described in the previous section. Calsite Inlay Investment responds to the hygroscopic technique to a much greater degree than does Kerr Cristobalite Investment. The expected advantage of 0.6 per cent. by using the hygroscopic expansion technique instead of the wet asbestos liner alone (as computed from Table 3) checks well with the 0.7

per cent. actual improvement in the specimens as cast in Calsite Inlay Investment at 800°C.

The response of Investo Universal Investment is small compared with the difference in expansion obtained by casting at 800°C. instead of 450°C. so that, in effect, using the hygroscopic technique and casting at 450°C. achieves much less compensation than simply casting at 800°C. The Universal Investment was unique in this respect giving a difference of about 0.7 per cent. in thermal expansions for 450 and 800°C. when determined according to the A.D.A. Tentative Specification No. 2[7]. On the other hand, the difference for Kerr Cristobalite was nil and for Calsite Inlay, 0.2 per cent.,

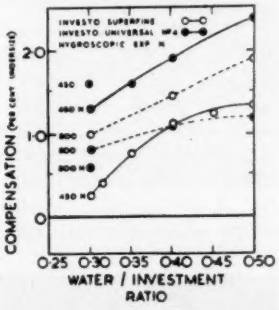

Figure 5.—Shrinkage compensation obtained on experimental castings using local investments. Temperatures shown are °C. The zero line represents exact reproduction of the pattern in gold.

using the same method. This difference agreed fairly well with those estimated from the results shown in Figures 5 and 6. A reasonably high thermal expansion at low mould temperatures is therefore essential to the proper application of the hygroscopic technique.

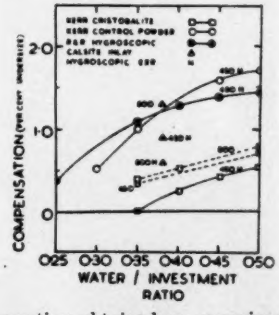

Figure 6.—Shrinkage compensation obtained on experimental castings using imported investments. Temperatures shown are °C.

With the hygroscopic technique and casting at a low mould temperature, Kerr Cristobalite and Investo Superfine Investments used with as thick a mix

[7]Taylor, N. O., Paffenbarger, G. C., and Sweeney, W. T.—Dental Inlay Casting Investments: Physical Properties and a Specification. J.A.D.A. 17: 2266-86 (1930).

as practicable appeared to be the most suitable of the investments tested, followed in order by R. & R. Hygroscopic, Kerr Control Powder, Calsite Inlay, and lastly, Investo Universal Investments.

(2) The next obvious conclusion is the importance of water-investment ratio. The necessity of thick mixes for maximum setting and thermal expansions is well known, but from the slope and shape of the curves in Figures 5 and 6 it is clear that the effect of change in the water-investment ratio is greater when the hygroscopic technique has been used. For instance with Investo Superfine, whereas the net casting shrinkage is about 0.2 per cent. for a water-investment ratio of 0.30 it becomes as great as 0.7 for a ratio of 0.35; the corresponding change where no hygroscopic expansion is employed is only 0.2 per cent. (from 1.0 to 1.2). The thickest practicable mix should therefore be used to exploit fully the hygroscopic expansion technique. In order to handle the thickest mixes possible it is desirable to adopt such devices as vacuum investing and adequate vibration of the investment around the pattern. It will be found that to enable these procedures to be carried out without undue haste the investment should have a reasonably long setting time.

(b) *MOD Steel Die.* In general the results obtained with the dimensioned cast specimens were confirmed wherever the tests were repeated using the MOD steel die. The degree of compensation could be observed by replacing the casting on the die after the removal of any nodules of gold on the contact

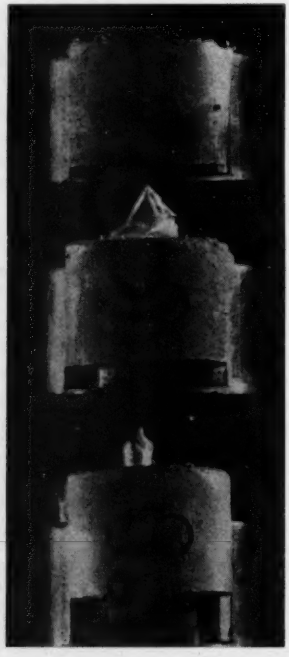

Figure 7.—Experimental MOD castings made with Investo Superfine Investment moulds using the hygroscopic expansion technique. Water-investment ratios as shown. Mould temperature: 450°C.

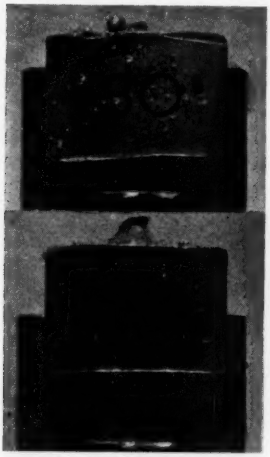

Figure 8.—Experimental MOD castings made with Investo Superfine Investment moulds without hygroscopic expansion. Water-investment ratios as shown. Mould temperature: 800°C.

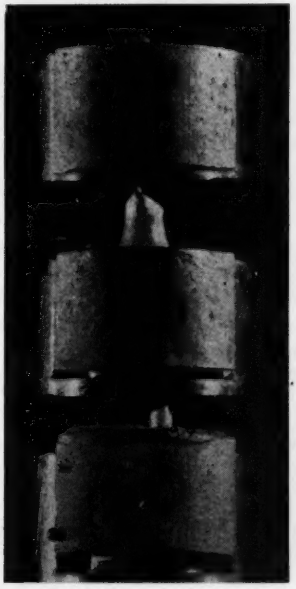

Figure 9.—Experimental MOD castings made with Kerr Cristobalite Investment moulds using the hygroscopic expansion technique. Water-investment ratios as shown. Mould temperature: 450°C.

surfaces, there being no other after-treatment of the castings. Undersized or distorted castings will not seat down perfectly on the tapered die and the discrepancy will be observed as a gap between the lower edge of the casting and the shoulder of the die. The results of these tests from castings prepared from Investo Superfine and Kerr Cristobalite moulds, using both normal and hygroscopic techniques, are shown in Figures 7 to 10 where the marked effect of water-investment ratio is again evident. These photographs are representative of from four to six castings, no endeavour being made to remove surface defects

Figure 10.—Experimental MOD castings made with Kerr Cristobalite Investment moulds without hygroscopic expansion. Water-investment ratios as shown. Mould temperature: 800°C.

other than those that would hinder the seating of the specimen. (The surface "bubbles" could have been avoided but vacuum mixing and investing were not used in these tests.)

Considering that distortion of patterns may contribute to the misfit of MOD inlays there is reasonably good correlation between the width of the gap and the discrepancies expected from the data represented in Figures 5 and 6, except perhaps for the specimens cast with Kerr Cristobalite without hygroscopic expansion. For some reason the latter are smaller than what would be expected from Figure 6. Repeat tests confirmed this discrepancy.

It is clear from these results that the hygroscopic technique offers improved compensation for casting shrinkage in addition to the advantages of low temperature casting.

(c) *Extracted Teeth.* Figures 11 and 12 compare castings based on wax patterns prepared in the normal manner but on extracted and mounted teeth. The patterns were drawn at room temperature but the temperature of immersion was the same, instead of 30 to 40°C. as advocated by most exponents of the hygroscopic technique. In the case of casting procedures without hygroscopic expansion, if the pattern were drawn in the mouth and invested at room temperature the fit could not be expected to be quite as good as illustrated due to the thermal contraction of the wax from oral to room temperature.

The results obtained in these tests confirmed those obtained in the previous section.

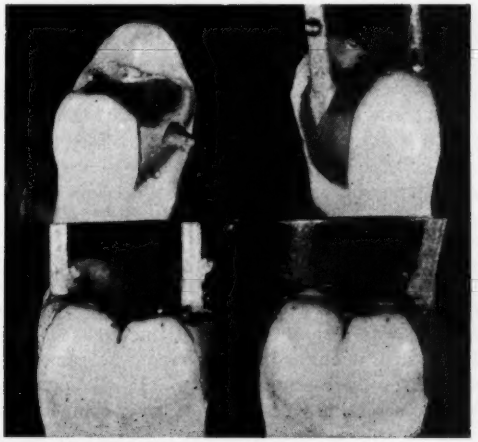

Figure 11.—Inlays prepared using Investo Superfine Investment. Water-investment ratio: 0.30. Lower right inlay cast in a mould at 800°C. without hygroscopic expansion. Others cast at 450°C. following the hygroscopic technique.

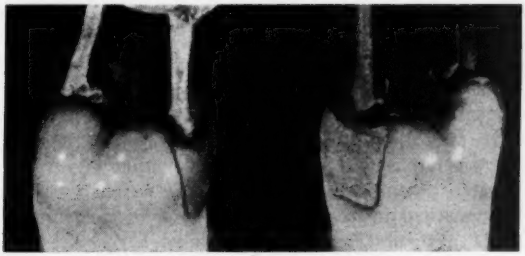

Figure 12.—Inlays prepared using Kerr Cristobalite Investment. Water-investment ratio: 0.35. Left: Inlay cast in a mould at 450°C. following the hygroscopic technique. Right: Inlay cast at 800°C. without hygroscopic expansion.

Other Experiments.

In addition to the tests outlined, several experiments were carried out to clarify various issues arising from them.

1. *Directional effects*: It is desirable to know whether there is any directional effect in the hygroscopic expansion obtained in the ring. Pairs of dimensioned wax patterns prepared as already described were joined at right angles and mounted on the sprue former so that one of the patterns was placed longitudinally and the other transversely (the normal position) in the ring. Investo Superfine Investment at a water-investment ratio of 0.50 and 0.30 was used, hygroscopic expansion effected and the specimens cast at 450°C. The results of measurements on this occasion are included in Table 5 and show that for the purpose of these experiments there is no significant directional effect.

TABLE 5
Directional Effect in Inlay Ring.
(Investo Superfine).

Water-investment ratio	Lateral direction	Longitudinal direction
	per cent. undersize	per cent. undersize
0.30	0.12	0.11
0.30	0.13	0.12
0.50	1.40	1.41
0.50	1.35	1.30

2. *Confinement in ring*: In studying the restriction imposed by the inlay ring some tests were carried out using a split wax ring in place of a metal one up to the time the ring was actually placed in the furnace. In some instances, if the investment was firm enough, the wax ring was removed prior to immersion in the water bath for hygroscopic setting. In all instances the expansions obtained were greater, sometimes resulting in over-compensation.

Results obtained by this method were not as reproducible as when a metal inlay ring was employed. Moreover, the use of a split ring with hygroscopic expansion is to be discouraged as expansion may be so great as to cause pronounced radial cracking from the split. Smyd[8] has clearly demonstrated this phenomenon with split metal rings.

3. *Pattern Distortion*: It has often been conjectured what happens to the wax inlay pattern when the investment undergoes a high hygroscopic setting expansion, and whether in turn the two proximal sections of an MOD pattern restrict the expansion of the investment held between them. Smyd[8] has considered on theoretical grounds the possibility that the expanding investment core in an MOD pattern may distort the wax structure by bending. This may be so with patterns that are not very hard at the temperature of investing, but careful sectioning of invested patterns immediately after extensive hygroscopic expansion at room temperature in the split wax ring just described, showed that experimental MOD patterns fracture diagonally across at least one of the angles between the occlusal and proximal sections. This allows either the mesial or distal section, or both, to be carried bodily away from the remainder of the pattern by the expanding investment. Of course the force necessary to fracture the wax may be sufficient to decrease the investment expansion; in fact, Smyd concluded from his experiments that it was desirable to use a relatively soft plastic wax in the hygroscopic technique.

4. *Time of immersion*: When investigating the effect of the time interval between mixing the investment and immersion of the ring in water the split wax ring already referred to was in use but the results were sufficient to indicate that with the two investments tested (Investo Superfine and Calsite Inlay) there was a definite increase in the actual expansion obtained as the time interval between mixing and immersion of the investment was shortened. The effect appears to be greater than what would be predicated from Tables 2 and 3. The advantage of hygroscopic expansion is lost if immersion is delayed until near or after the initial setting time. This constitutes another advantage

[8]Smyd, E. S.—Factors which Influence Casting Accuracy: A Universal Casting Technique. J.A.D.A. 36: 160-72 (1948).

in having a relatively long setting time in investments for the hygroscopic technique.

5. *Effect on thermal expansion*: It was of interest to observe what effect hygroscopic expansion had on the subsequent thermal expansion of an investment. It is obvious from the data in Figures 5 and 6 that the total expansion obtained by the hygroscopic-thermal expansion procedure is greater than that obtained by thermal expansion alone, although this advantage varies according to the investment. Tests indicate that the thermal expansion curves for Investo Superfine, Calsite Inlay, and Kerr Cristobalite Investments after a hygroscopic expansion are not substantially different from those obtained in the normal manner.

One further point established in regard to thermal expansion of the investments tested was that it was not appreciably affected by carrying out the test at as short a period as one hour after mixing instead of allowing time for the specimens to dry out. This is somewhat relevant to the procedure referred to previously, i.e., placing the lined ring in the furnace at 450°C. directly after removal from the water bath.

Surface Finish.

One of the chief advantages of the hygroscopic expansion technique is that one should not have to rely on heating the mould to very high temperatures to achieve the necessary expansion and compensation, lower temperatures may be used with consequent improvement in surface finish of the casting. An examination of the castings from this and subsequent series of tests indicate that the ranking of the investments tested is as shown in Table 6.

TABLE 6

Surface Finish of Castings.

Assessment	Investment	Casting Temperature	
		°C.	°F.
Good	Investo Superfine, Kerr Cristobalite, Calsite Inlay (equal)	450	840
Fairly good	Kerr Control Powder	450	840
Fair	Investo Universal	450	840
	R. & R. Hygroscopic	450	840
	Investo Superfine, Kerr Cristobalite, Calsite Inlay (equal)	800	1470
Poor	Investo Universal	800	1470

These results apply to the thicker mixes of the investments tested and the advantage of casting at the lower temperature is confirmed.

It was observed that thin mixes resulted in poorer surface finish. Castings made in high temperature moulds of "thin" investment were difficult to clean owing to a tenaciously held film of investment or of one of its components. Ireland[9] recently studied the surface finish of castings and also found that one of the chief factors in improving this property is the use of thick mixes. He also concluded that hygroscopic expansion did not have any influence on the surface finish. This does appear to be the case, the value of the hygroscopic

[9]Ireland, J.—Vacuum Investing and its Relation to Cast Surfaces. B.D.J. 86: 111-8 (1949).

technique being chiefly due to the thicker investment mixes used and the lower mould temperatures required.

Clinical Results.

Hygroscopic setting expansion is used very extensively in dental casting and appears to be particularly popular in some centres in the U.S.A. at least. There the process is usually considered as an integral part of the Hollenback technique[10], which incorporates other refinements such as vacuum mixing and investing that also contribute to superior castings.

There is no doubt that hygroscopic setting expansion of dental investments, whether part of the Hollenback technique or otherwise, is capable of producing excellent clinical results. Smyd[8] considers that of the methods used for overcoming the casting shrinkage of gold "the one emphasising hygroscopic expansion seems to be the most consistent in producing well compensated castings." Referring to the Hollenback technique Tylman[11] claims that "castings made by this method are extremely smooth and accurate," and another authority, Skinner[12], considers that "it is today, in the hands of an operator who understands it, the most accurate method for the casting of gold inlays." Hollenback[10] found that without any variation in his technique it would "reproduce precisely and consistently any wax patterns regardless of type or complication."

These statements summarise the clinical and general experience as reported in overseas literature. On the other hand, it appears that very few Australian practitioners employ hygroscopic setting expansion as a deliberate step in their technique for the casting of inlays and crowns. However, sufficient information is forthcoming here to confirm the opinions expressed in reports from other countries. The opportunity was taken on one occasion to check quantitatively the efficacy of a routine hygroscopic procedure employed in a dentist's laboratory. Using dimensioned wax patterns as previously described the corresponding castings were found to be not more than 0.1 per cent. undersize, which is an improvement on what could be achieved with the conventional procedure excluding the use of hygroscopic setting expansion. The practitioner stated that these results were fully confirmed in his clinical experience. In practice it will be necessary to adjust the conditions of investing and casting according to the type of alloy to be cast. This is best determined by experiment, varying the water-investment ratio according to the expansion desired.

In this connection it would appear, from the results summarised in this paper, that the thickness of the mixed investment is the most convenient and reliable method for controlling the expansion. It is the method of control used by Hollenback[10], and should be more satisfactory than the earlier method proposed by Scheu[13] who controlled hygroscopic setting expansion by adjusting the time interval between the mixing of the investment and the immersion of the invested pattern in water.

Apart from the adjustment of water-investment ratio according to the casting alloy to be used, no other variation in the hygroscopic procedure is necessary irrespective of the shape or size of the inlay, crown or bridge.

[10]Hollenback, G. M.—Simple Technique for Accurate Castings: New and Original Method of Vacuum Investing. J.A.D.A. 36: 391-7 (1948).

[11]Tylman, S. D.—"Theory and Practice of Crown and Bridge Prosthesis." 2nd ed., London, Henry Kimpton, 1947, pp. 423-38.

[12]Skinner, E. W.—Present Status of the Inlay Casting Technique. Illinois Dental J. 15: 499-504 (1946).

[13]Scheu, C. H.—A New Precision Casting Technique. J.A.D.A. 19: 630-3 (1932).

General Conclusions.

From the results of these investigations and clinical experience elsewhere a number of more important conclusions may be listed.

(1) The immersion of a freshly filled casting ring in water produces an additional setting expansion of the investment, and the amount of this hygroscopic setting expansion depends on the type of investment used and the technique adopted.

(2) The extra expansion obtained may be made use of in two ways:—

(a) to provide more adequate compensation for the casting shrinkage of the alloy used,

(b) to enable lower mould temperatures to be used, with resulting advantages such as superior surface finish in the casting.

(3) The amount of hygroscopic expansion obtained depends on a number of factors the more important being—

(a) *Nature of investment*: The fineness and proportion of silica, in experimental investments at least, are most important. Commercial investments vary greatly in their response to hygroscopic expansion.

(b) *Water-investment ratio*: The thickness of the investment mix is probably the most useful variable for controlling the degree of hygroscopic expansion. It is important to use a thick mix for it not only increases the hygroscopic setting expansion but improves the surface finish also.

(c) *Time interval between mixing and immersion*: As a rule this period should be kept as short as practicable for the best and most reproducible results.

(d) *Confinement in the ring*: The casting ring must be lined, preferably with wet asbestos.

(4) An investment designed for the hygroscopic technique should not only have (a) the usual desirable properties of dental casting investments and, (b) good response on immersion in water, but should also have (c) a reasonably long setting time. This will enable very thick mixes to be used and diminish the effect of the time interval between mixing the investment and immersion of the ring. Finally, a hygroscopic investment should not only have (d) a reasonably good thermal expansion at about 450°C. (840°F.), but it is desirable for it to have (e) a comparatively flat thermal expansion curve in this region to allow some latitude in the mould casting temperature.

Acknowledgements.

The thanks of the authors are due to those who have assisted in the preparation of this paper. The staff of the Conservative Department of the Dental School, University of Melbourne, kindly undertook the preparation of inlay patterns. Several members of the dental profession willingly supplied useful information on the clinical aspects of the hygroscopic technique, and some assisted by casting experimental specimens.

SOME OBSERVATIONS ON DENTAL CONDITIONS IN PAPUA—NEW GUINEA, 1947, WITH SPECIAL REFERENCE TO DENTAL CARIES

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PART VII.

DENTAL CARIES.

INTRODUCTION.

There is a tendency to regard the words 'native diet' as synonymous with 'ideal diet' and as implying *ipso facto* 'freedom from dental caries.' This view is held often uncompromisingly and without due consideration of the nature of any particular diet or how the food is prepared and without proper realisation of how great 'native diets' differ from each other. The data discussed in this Part of the paper will show the need for a review of this belief[53].

[53]Richards, A. I.—Land, labour and diet in northern Rhodesia. An economic study of the Bimba tribe, London, 1939.

*Members of the New Guinea Nutrition Survey Expedition, 1947.

†Working with the aid of a grant from the National Health & Medical Research Council of Australia.

As mentioned earlier, our principal object was to obtain data on certain aspects of dental caries and to this end the people of three villages were studied. In this Part of the paper, then, we shall attempt to interpret our observations in relation to the observations of the medical officer, nutritionist and agronomist.

Data from these reports have been included in a summarised form where necessary.

Examination of Natives.

A. Subjects.

In Pātep II, 136 natives out of a total population of 156 were examined. In the larger villages of Kavataria and Korovagi an attempt was made to examine the members of every third household. This plan worked well in Kavataria, but in Korovagi we were able to examine only those who were willing to visit the camp. In both villages about 100 (approximately one-third of the population) were examined. Children under the age of one year were not examined.

B. Materials.

(a) Such equipment as was necessary for clinical and radiographical examination of the oral structures was taken.

(b) A kerosene-operated autoclave, incubator and refrigerator were taken in addition to the usual laboratory requisites.

(c) Robertson's cooked meat medium was prepared in small bottles in the Institute and used for the preservation and transportation of cultures.

(d) McConkey's medium and desoxycholate medium (both for the isolation of gram-negative rods: Bacterium) were carried in the dried form and reconstituted as required at the various stations.

(e) Tomato peptone agar[54] (for the isolation of Lactobacillus and Candida) was prepared in bulk at the Institute in Sydney and shipped to New Guinea.

C. Methods.

(a) *Clinical Examination.* The subjects were seated on a stool in the shade, but so placed that there was adequate light. All accessible tooth-surfaces were examined with the aid of plane mirrors and sharp, right-angle explorers.

Any pit or fissure into which the probe could be introduced to such a depth that it would remain fast was considered to be carious.

(b) *Radiographical Examination.* Five intra-oral films were exposed in each examination, three for the upper anterior teeth and two bitewings for the posterior teeth. Eastman Kodak 'Radiatized' films were used in Pātep II and Ilford No. 5 in Kavataria and Korovagi. In order to get the best results with the somewhat inadequate apparatus it was necessary to have a long exposure. The use of five films per native in Pātep II meant that each individual was subjected to a total exposure of 76 seconds, which was considered the maximum consistent with safety. In Korovagi and Kavataria, where the Ilford speed films were used, each native was subjected to a total exposure of 34 seconds. Young children were not examined as they could not remain motionless long enough.

After development, the films were examined and any clinically undetected lesions were recorded. By no means all of the radiograms obtained were entirely satisfactory. The outline of the pulp chamber and the differentiation of

[54]Kulp, W. L. and White, V.—A modified medium for plating Lactobacillus acidophilus, Science, 76:17, 1932.

the enamel and dentine were usually clear, but the detail was often insufficient to show whether there were small cavities in the approximal surfaces of the teeth.

(c) *Recording the Observations.* The native people were unable to give accurate information about their age. The subjects in each village have, therefore, been divided into what may be termed physiological age-groups, determined in the children by the eruption-time of their teeth and in adults by the general physical appearance.

Group A :	12 or more deciduous teeth	approx. age 1- 5 years
„ B :	1 or more first permanent molars	approx. age 6-10 years
„ C :	1 or more second permanent molars	approx. age 11-15 years
„ D :	1 or more third permanent molars and/or adults up to approx. 29 years	approx. age 16-29 years
„ E :	middle-aged adults	approx. age 30-44 years
„ F :	old people	approx. age 45 and over 45 years

A similar method has been used by other workers (Campbell[4] (*loc. cit.*, p. 7)).

Missing permanent teeth, roots and surfaces affected by caries were marked on geometric charts similar to that described by Bodecker[55]. Slight modifications were made in the recording of deciduous teeth.

Caries-incidence in each village is recorded in several ways:

1. On the basis of *persons.* The individuals in the various age-groups are divided into (i) caries-free persons, (ii) persons free of evidence of caries other than retained roots, (iii) persons with caries.

2. On the basis of *standing teeth.** The distribution according to age-group of both carious and sound teeth is shown. Missing teeth and roots were disregarded so that relevant tables record only facts as observed.

3. On the basis of *surfaces* of standing teeth.* In this survey we have expressed the number of carious surfaces observed as a percentage of the total number of tooth-surfaces in each age-group. Roots and missing teeth have been excluded.

*When examining a native population, it is often necessary to make assumptions concerning the causes of the loss of teeth. Therefore a caries index, calculated in the manner described by Bodecker[55], may possibly be misleading. Also, the fact that the members of a specified age-group do not necessarily have the same number of teeth present in the mouth may permit of considerable error when an attempt is made to compare various age-groups (Hewat[56]).

A value for each individual was calculated, using the formula—

$$\frac{\text{number of carious surfaces present}}{\text{total number of surfaces present}} \times 100$$

[55]Bodecker, C. F.—The modified dental caries index, J.Amer.Dent.Ass., 26:1453, 1939.

[56]Hewat, R. E. T.—Field studies on dental caries in New Zealand, N.Z.Dent.J., 44: 163, 1948.

Permanent teeth were considered by us (as by Bodecker) to possess a total of 180 surfaces. Deciduous teeth were considered to possess a total of 108 surfaces, or 8 more than Bodecker's number. The extra surfaces are (i) on the occlusal aspect of each of the deciduous maxillary molars, and (ii) on the buccal aspect of the deciduous mandibular molars (as distinct from the gingival third of this aspect) where there is almost invariably a caries-susceptible pit present.

The mean and median for each age-group and the distribution of the individual percentages were also calculated. Percentages were not calculated for the few subjects who had some roots present but otherwise were caries free.

4. On the basis of *teeth, including missing teeth.* Where deficiencies were assumed to have been caused by caries the teeth involved were included among the carious teeth to give the DM* total. The bases on which the assumptions were made are elaborated later under the section entitled 'Missing teeth and probable causes'.

In paragraphs 1, 2 and 3 above, in those age-groups where the subjects possessed mixed dentitions, figures are given for the two dentitions both separately and jointly. The 'deciduous group' includes the children with only deciduous teeth. The 'permanent group' includes those with only permanent teeth.

(d) *Collection and examination of samples of saliva for bacteriological purposes.* The subjects were the same as those studied clinically; European members of the party were used for control observations.

For our present purposes and in view of the taxonomical difficuties we have defined a Lactobacillus in the following way: a rod, varying in length from very short (approx. 2 μ) to filamentous (more than 15 μ), gram-positive, non-motile, non-sporing, non-proteolytic (gelatin), producing acid from various carbohydrates and capable of growth in primary and succeeding cultures on tomato-peptone agar (and not possessing any of the more obvious distinctive features of other recognised gram-positive rods). This definition conforms to but is less specific than that given by Wilson and Miles[57]. In the analysis of results no distinction is drawn between strains on the basis of their relative powers of acidogenesis (Sullivan et alii[58]).

Other details of the investigations of the strains of Lactobacillus from New Guinea natives will be published separately (Goldsworthy[59]).

The examination was conducted along lines essentially similar to those followed in investigations in America and elsewhere. The main points are these: the subject was asked to chew a piece of paraffin-wax for five minutes

*D = decayed; M = missing.

[57]Wilson, G. S. and Miles, A. A.—Topley and Wilson's principles of bacteriology and immunity, 3rd ed., London, p.750, 1946.

[58]Sullivan, H. R., Still, J. L. and Goldsworthy, N. E.—Acid production as a basis for classifying lactobacilli from carious teeth, J.Dent.Res., 18:513, 1939.

[59]Goldsworthy, N. E.—Personal communication.

and to eject the saliva into a suitable vessel. The sample of saliva was stood aside while the clinical examination was carried out and the bacteriological specimens from the previous sample of saliva were examined. The samples of saliva were invariably collected between 8 a.m. and 9.30 a.m. and plated out as soon as possible but rarely before they had stood for 3 to 8 hours. When stood for the longer periods they were placed in the refrigerator. According to common practice, dilutions of saliva were prepared in broth and measured quantities of these distributed over (i) three tomato-peptone agar plates; (ii) one McConkey's agar plate and (iii) one desoxycholate agar plate. The plates were incubated at 37°C. for a maximum of 72 hours. As a rule the two bile-containing media were examined after 24-48 hours and the tomato-peptone agar after 72 hours. The numbers of the different kinds of colonies on the various media were counted and recorded, after which any colonies deemed to be of interest were selected and transferred into cooked meat medium. These subcultures were incubated overnight and then stored in a refrigerator at approximately 4°C. From the same or similar colonies films were prepared for miscroscopic study. Films were made also from the whole saliva. All films were allowed to dry, fixed by heat and wrapped and stored for transport to the Institute. It proved impossible in the time available at the various stations to make any microscopic examinations.

(e) *Collection of other relevant data (e.g. dietary).* Reference should be made to the Report of the New Guinea Nutrition Survey Expedition, 1947[42].

RESULTS.

A. Description of Carious Lesions.

In most characteristics, carious lesions were similar in appearance to those found in white races. However, the white, opaque appearance of decalcified enamel was practically never observed because the teeth were so frequently stained with betel nut. Almost invariably, exposed carious dentine was black and much tougher and more leathery than the pale yellow or light brown carious dentine observed in white races (civilised conditions).

B. Prevalence, Incidence and Age-distribution of Dental Caries.

(a) *Persons.* Tables 16-18 show the distribution, according to age-group, of (i) caries-free persons; (ii) persons free of evidence of caries other than retained roots; and (iii) persons with caries.

It seemed instructive to compare, on the basis of percentage of caries-free persons, the incidence of caries in the total population of each of the three villages with that in some other native races and in white people. Table 19 shows these figures, but it should be borne in mind that there are numerous variables, for example, observers, age-distribution of population, source of data (skulls or living subjects) and choice of diagnostic techniques.

(b) *Teeth.* In many respects the dental health of a community is more clearly indicated by figures giving the number of teeth both carious and sound than by numbers of persons with or without caries. Such figures are shown in tables 20-22 and may be compared with those of (i) Cunningham[65], who in his report on the work of the Cambridge Dental Clinic showed that 29% of the teeth of the children examined were carious, and of (ii) Campbell[4] (*loc. cit.*,

[65]Cunningham, G.—Experience of a school dental clinic—Cambridge Dental Institute, Brit.Dent.J., 29:870, 1908.

p. 75), who showed that for Australian aborigines (all ages) of 10,561 teeth examined 167 (or 1.58%) were carious.

TABLE 16 (A).
PĀTEP II.
Percentage of Caries-free Subjects.

Group	Approx. Age (years)	Number of Subjects				% subjects caries-free
		examined	caries-free	with caries	with roots present, other teeth caries-free	
A	1–5	23	18	5	0	78.26
B	6–10	14	8	6	0	57.14
C	11–15	12	9	3	0	75.00
D	16–29	46	19	24	3	41.30
E	30–44	23	6	14	3	26.09
F	45 and over	18	1	15	2	5.56
	Totals	136	61	67	8	44.85

TABLE 16 (B).
PĀTEP II.
Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	Number of Subjects			% subjects caries-free
			examined	caries-free	with caries	
B	6–10	Deciduous teeth	14	10	4	71.43
		Permanent teeth	14	10	4	71.43

TABLE 17 (A).
KAVATARIA
Percentage of Caries-free Subjects.

Group	Approx. Age (years)	Number of Subjects.				% subjects caries-free
		examined	caries-free	with caries	with roots present, other teeth caries-free	
A	1–5	8	3	5	0	37.50
B	6–10	13	2	11	0	15.38
C	11–15	13	4	9	0	30.77
D	16–29	19	15	4	0	78.95
E	30–44	26	21	4	1	80.77
F	45 and over	15	7	6	2	46.67
	Totals	94	52	39	3	55.32

TABLE 17 (B).
KAVATARIA
Data for Groups B and C (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	Number of Subjects			% subjects caries-free
			examined	caries-free	with caries	
B	6–10	Deciduous teeth	12	3	9	25.00
		Permanent teeth	13	7	6	53.85
C	11–15	Deciduous teeth	3	2	1	66.67
		Permanent teeth	13	5	8	38.46

TABLE 18 (A).
KOROVAGI
Percentage of Caries-free Subjects.

Group	Approx. Age (years)	Number of Subjects				% subjects caries-free
		examined	caries-free	with caries	with roots present, other teeth caries-free	
A	1–5	9	6	3	0	66.67
B	6–10	19	11	8	0	57.89
C	11–15	10	7	3	0	70.00
D	16–29	17	13	4	0	76.46
E	30–44	32	22	10	0	68.75
F	45 or over	41	11	2	1	78.57
	Totals	101	70	30	1	69.31

TABLE 18 (B).
KOROVAGI
Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	Number of Subjects			% subjects caries free
			examined	caries-free	with caries	
B	6–10	Deciduous teeth	18	10	8	55.56
		Permanent teeth	19	18	1	94.74

TABLE 19
Percentage of Caries-free Subjects in Different Races.

Observer	Approx. Age	Skulls or living subjects	Geographical location	Number observed	% subjects caries-free
Turner[60]	mixed	skulls (ancient)	Egypt	104	59.62
Campbell[4]	mixed	skulls	Australia (Aborigines)	583	86.45
Kirkpatrick[61]	mixed	living subjects	Manus (Admiralty Is.)	1976	97.50
Colyer[62]	adult males	living subjects	Central Africa	700	88.90
Cameron[63]	children 0–12 yrs.	living subjects	Australia (white)	1745	10.09
Schleswig-Holstein Dent. Assn.[64]	school-children	living subjects	Northern Germany	19725	5.00
Present writers	all ages	living subjects	Pătep II	136	44.85
			Kavataria	94	55.32
			Korovagi	101	69.31

[60]Turner, J. G.—Cited by Colyer, J. F. and Sprawson, E., Dental surgery and pathology, 8th ed., London, p.301, 1946.
[61]Kirkpatrick, R. M.—Dental caries and odontoclasia in New Guinea, Dent.J.Aust., 7:707, 1935.
[62]Colyer, J. F. and Sprawson, E.—Dental surgery and pathology, 8th ed., London, p.305, 1942.
[63]Cameron, D. A.—Personal communication.
[64]Anonymous—Cited by Pickerill, H. P., Prevention of dental caries and oral sepsis, London, p.10, 1912.

TABLE 20 (A).

PĀTEP II

Percentage of Carious Teeth.

Group	Approx. Age (years)	No. subjects examined	Number of Teeth		% carious teeth
			standing	carious	
A	1–5	23	460	12	2.61
B	6–10	14	333	23	6.91
C	11–15	12	332	7	2.11
D	16–29	46	1408	71	5.04
E	30–44	23	675	57	8.44
F	45 and over	18	399	58	14.54
	Totals	136	3607	228	6.32

TABLE 20 (B).

PĀTEP II

Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	No. subjects	Number of Teeth		% carious teeth
				standing	carious	
B	6–10	Deciduous teeth	14	177	13	7.34
		Permanent teeth	14	156	9	5.77

TABLE 21 (A).

KAVATARIA

Percentage of Carious Teeth.

Group	Approx. Age (years)	No. subjects examined	Number of Teeth		% carious teeth
			standing	carious	
A	1–5	8	159	32	20.13
B	6–10	13	306	47	15.36
C	11–15	13	357	18	5.04
D	16–29	19	602	5	0.83
E	30–44	26	804	5	0.62
F	45 and over	15	301	7	2.32
	Totals	94	2529	114	4.51

TABLE 21 (B).

KAVATARIA

Data for Groups B and C (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	No. subjects	Number of Teeth		% carious teeth
				standing	carious	
B	6–10	Deciduous teeth	12	159	37	23.27
		Permanent teeth	13	147	10	6.80
C	11–15	Deciduous teeth	3	3	1	33.33
		Permanent teeth	13	354	17	4.80

TABLE 22 (A).
KOROVAGI
Percentage of Carious Teeth.

Group	Approx. Age (years)	No. subjects examined	Number of Teeth		% carious teeth
			standing	carious	
A	1–5	9	168	6	3.57
B	6–10	19	451	31	6.87
C	11–15	10	280	8	2.86
D	16–29	17	524	10	1.91
E	30–44	32	1013	19	1.88
F	45 and over	14	416	3	0.72
	Totals	101	2852	77	2.77

TABLE 22 (B).
KOROVAGI
Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. Age (years)	Subjects with	No. subjects	Number of Teeth		% carious teeth
				standing	carious	
B	6–10	Deciduous teeth	18	242	28	11.57
		Permanent teeth	19	209	3	1.43

(c) *Surfaces of Standing Teeth.* Tables 23-25 give an index of dental caries calculated on the basis of the formula previously given. It should be noted that in each village the individual percentages are nearly all below 5, and only a scattered minority falls within the range of higher values.

TABLE 23 (A).
PĀTEP II
Percentage of Carious Tooth-surfaces.

Group	Approx. age (years)	No. subjects examined	No. of surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
			standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
A	1–5	23	2484	22	0.89	0.00	21	2	0	0	0
B	6–10	14	1861	32	1.72	0.00	12	2	0	0	0
C	11–15	12	1847	12	0.65	0.00	12	0	0	0	0
D	16–29	43	7390	95	1.29	0.60	41	1	1	0	0
E	30–44	20	3280	81	2.47	2.05	16	4	0	0	0
F	45 and over	16	2205	88	3.99	3.23	12	2	1	1	0
	Totals	128*	19067	330	1.73	0.60	114	11	2	1	0

* 136–8 (subjects with roots but other teeth caries-free) = 128.

TABLE 23 (B).
PĀTEP II
Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. age (years)	Subjects with	No. subjects examined	No. surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
				standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
B	6–10	Deciduous teeth	14	997	19	1.91	0.00	11	1	1	1	0
		Permanent teeth	14	864	13	1.50	0.00	13	1	0	0	0

TABLE 24 (A).
KAVATARIA
Percentage of Carious Tooth-surfaces.

Group	Approx. age (years)	No. subjects examined	No. surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
			standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
A	1–5	8	859	47	**5.47**	1.38	5	1	0	2	0
B	6–10	13	1701	71	**4.17**	2.98	9	3	0	1	0
C	11–15	13	1977	24	**1.21**	0.69	13	0	0	0	0
D	16–29	19	3383	5	**0.15**	0.00	19	0	0	0	0
E	30–44	25	4332	9	**0.21**	0.00	25	0	0	0	0
F	45 and over	13	1589	10	**0 63**	0.00	13	0	0	0	0
	Totals	91*	13841	166	**1.20**	0.00	84	4	0	3	0

* 94—3 (subject with roots but other teeth caries-free) = 91.

TABLE 24 (B)
KAVATARIA
Data for Groups B and C (Subjects with Mixed Dentitions).

Group	Approx. age (years)	Subjects with	No. subjects examined	No. surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
				standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
B	6–10	deciduous teeth	12	884	58	**6.56**	2.40	8	0	2	0	2
		permanent teeth	13	817	13	**1.59**	0.00	12	1	0	0	0
C	11–15	deciduous teeth	3	17	1	**5.88**	0.00	2	0	0	0	1
		permanent teeth	13	1960	23	**1.17**	0.64	13	0	0	0	0

TABLE 25 (A).
KOROVAGI
Percentage of Carious Tooth-surfaces.

Group	Approx. age (years)	No. subjects examined	No. surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
			standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
A	1–5	9	904	6	**0.66**	0.00	9	0	0	0	0
B	6–10	19	2508	42	**1.67**	0.00	17	1	1	0	0
C	11–15	10	1560	10	**0.64**	0.00	10	0	0	0	0
D	16–29	17	2946	10	**0.34**	0.00	17	0	0	0	0
E	30–44	32	5694	29	**0.51**	0.00	32	0	0	0	0
F	45 and over	13	2217	4	**0.18**	0.00	13	0	0	0	0
Totals		100*	15829	101	**0.64**	0.00	98	1	1	0	0

* 101—1 (subject with roots but other teeth caries-free) = 100.

TABLE 25 (B).
KOROVAGI
Data for Group B (Subjects with Mixed Dentitions).

Group	Approx. age (years)	Subjects with	No. subjects examined	No. surfaces		% carious surfaces per person		Distribution of population according to % carious surfaces				
				standing	carious	mean	median	0–4%	5–9%	10–14%	15–19%	20%
B	6–10	deciduous teeth	18	1344	36	**2.68**	0.00	15	2	0	0	1
		permanent teeth	19	1164	6	**0.52**	0.00	18	1	0	0	0

(d) *Teeth, including Missing Teeth.* Table 26 shows the number of defective and missing teeth per person in the different age-groups. The DM figure probably gives a better indication of the amount of caries than any other single method of assessment in spite of possible errors arising from assumptions concerning the causes of missing teeth in the adult age-groups.

TABLE 26

Mean Number of DM Teeth per Person.

Group	Approx. Age (years)	Pātep II		Kavataria		Korovagi	
		No. persons	Mean No. DM teeth per person	No. persons	Mean No. DM teeth per person	No. persons	Mean No. DM teeth per person
A	1–5	23	0.52	8	4.12	9	0.67
B	6–10	14	1.64	13	3.62	19	1.74
C	11–15	12	0.58	13	1.46	10	0.80
D	16–29	46	2.13	19	0.32	17	0.59
E	30–44	23	4.30	26	0.27	32	0.59
F	45 and over	18	12.61	15	0.27*	14	0.57
	Totals	136	3.43	94	1.23*	101	0.83

* Owing to the impossibility of determining whether loss was due to caries or other causes, we have assumed that the trend of the figures in this column is constant. We could, therefore, on this basis postulate not more than 0.27 DM teeth per person and thus arrive at a probable maximum figure of 1.23 DM teeth per person for the whole village.

A comparison may be made between the number of DM teeth per child in New Guinea and in New Zealand (Hewat[56]). Table 27 shows that the lowest figures for the New Zealand groups are considerably higher than the highest of the corresponding figures for the New Guinea groups. There are, however, certain differences between the two groups, namely that many of the New Zealanders had had bitewing-radiograms made and the group was much larger, 1851 in all; also that the age-grouping of the New Guinea children was only approximate. However it is unlikely that these differences alone could explain the great discrepancy between the DM figures for the two groups.

TABLE 27

Number of DM Teeth per Child in New Guinea and New Zealand.

Group	NEW GUINEA				NEW ZEALAND	
	Approx. Age (years)	Pātep II	Kavataria	Korovagi	Approx. Age (years)	DM teeth per child
		teeth per child				
B	6–10	1.64	3.62	1.74	7	11.17
					8	11.45
					9	11.54
					10	8.59
C	11–15	0.58	1.46	0.89	11–12	9.41
					13	14.10
					14	16.53
					15	17.46

C. Site of Election of Dental Caries in Permanent Teeth.

Table 28 shows for each age-group the frequency with which the various surfaces of the teeth have been affected by caries.[8]. These results have been

TABLE 28

The Number of P : F : G* Surfaces in the Permanent Teeth attacked by Caries.
(Walsh & Smart's method.)

Group	Approx. Age (years)	Pātep II		Kavataria		Korovagi	
		No. persons	total P : F : G	No. persons	total P : F : G	No. persons	total P : F : G
B	6–10	14	0 : 9 : 1	13	0 : 9 : 3	19	0 : 0 : 6
C	11–15	12	1 : 7 : 1	13	4 : 13 : 3	10	0 : 8 : 2
D	16–29	46	15 : 55 : 10	19	0 : 4 : 1	17	1 : 5 : 4
E	30–44	23	20 : 41 : 8	26	2 : 3 : 3	32	20 : 7 : 2
F	45 and over	18	49 : 13 : 16	15	5 : 3 : 2	14	1 : 2 : 0

* P = proximal ; F = fissure ; G = gingival.

PĀTEP II

Group	Approx. Age (years)	No. subjects	Total no. carious surfaces	
A	1–5	23	22	F = 8 P = 7 G = 7
B	6–10	14	29	Deciduous : F = 7 P = 4 G = 5 Permanent : F = 12 P = 0 G = 1
C	11–15	12	12	F = 10 P = 1 G = 1
D	16–29	46	95	F = 70 P = 15 G = 10
E	30–44	23	81	F = 53 P = 20 G = 8
F	45 and over	18	87	F = 22 P = 49 G = 16

Location of Lesions

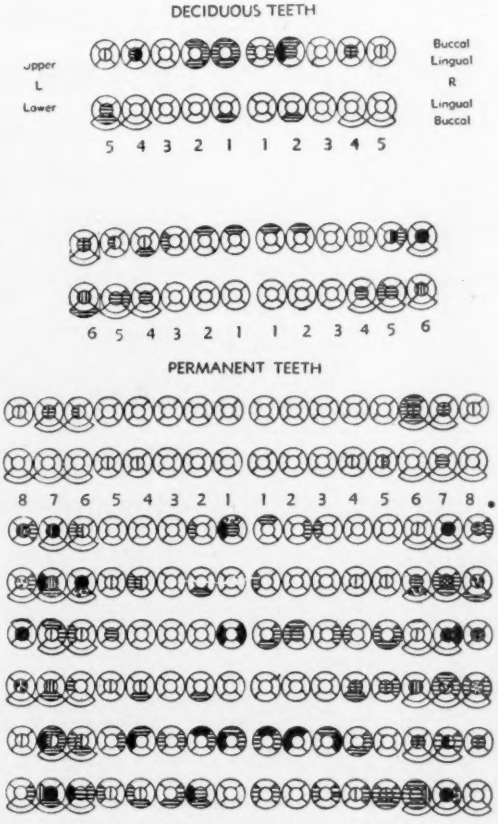

Fig. 56

Frequency with which individual surfaces were attacked by caries.
(*The diagram is intended to show that seven teeth had carious mesial occlusal pits and eight teeth had carious distal occlusal pits.)

determined in the same way as were those of Walsh & Smart[66] and can therefore be compared with theirs (table 29). It will be seen from table 28 that the P : F ratio is lowest in the youngest age-groups but that it gradually increases with age until in the over 45 age-group it is greater than unity.

KAVATARIA

Group	Approx. Age (years)	No. subjects	Total no. carious subjects	
A	1–5	8	47	F = 5 P = 31 G = 11
B	6–10	13	71	F = 15 P = 33 G = 10 F = 10 P = 0 G = 3
C	11–15	13	24	*Deciduous : P = 1 Permanent : F = 16 P = 4 G = 3
D	16–29	19	5	F = 4 P = 0 G = 1
E	30–44	26	9	F = 4 P = 2 G = 3
F	45 and over	15	10	F = 3 P = 5 G = 2

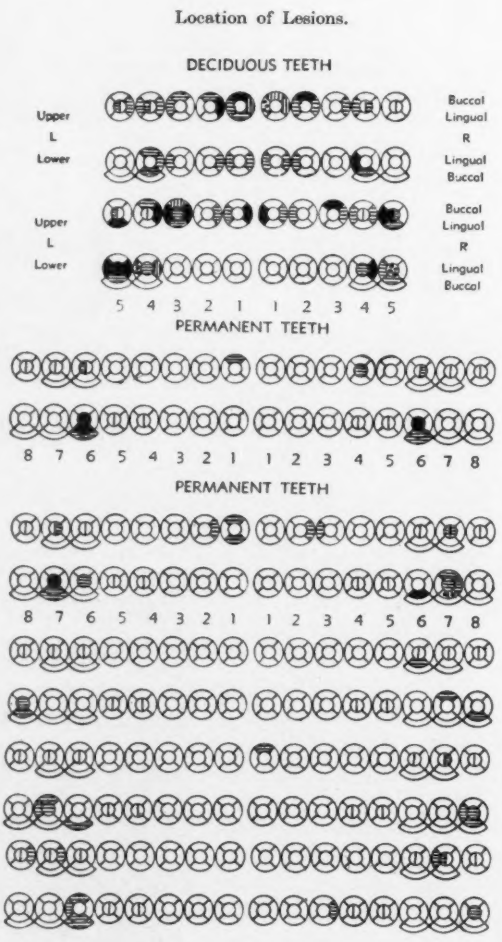

Fig. 57

Frequency with which individual surfaces were attacked by caries.
(*This lesion is not shown but was on the distal approximal surface of an upper right canine.)

KOROVAGI.

Group	Approx. Age (years)	No. subjects	Total no. carious surfaces	
A	1–5	9	6	F = 0 P = 4 G = 2
B	6–10	19	42	F = 4 P = 17 G = 15
				F = 0 P = 0 G = 6
C	11–15	10	10	F = 8 P = 0 G = 2
D	16–29	17	10	F = 5 P = 1 G = 4
E	30–44	32	29	F = 7 P = 20 G = 2
F	45 and over	14	4	F = 3 P = 1 G = 0

Location of Lesions.

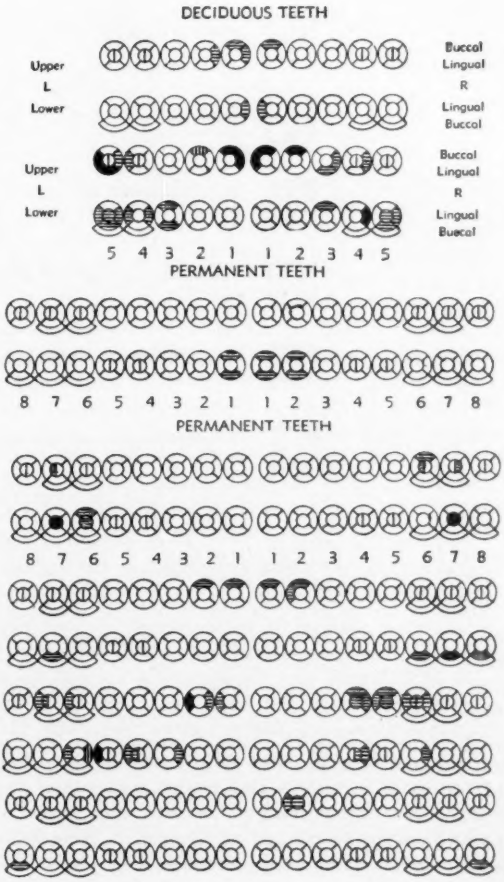

Fig. 58

Frequency with which individual surfaces were attacked by caries.
F = fissure, P = proximal, G = gingival.

§Figs. 56-58 also show the frequency with which individual surfaces of the teeth have been attacked by caries. However there is a discrepancy between them and Table 28 as our examination charts (pp. 131-133) from which the figures were compiled included several more tooth-surfaces than did those of Walsh and Smart.

Represents one surface attacked by dental caries.

Represents two surfaces attacked by dental caries.

Represents three surfaces attacked by dental caries.

Represents four surfaces attacked by dental caries.

Represents five surfaces attacked by dental caries.

Represents six surfaces attacked by dental caries.

Represents seven surfaces attacked by dental caries.

Represents eight surfaces attacked by dental caries.

Key to signs used in Figs. 56-58.

Several differences in the frequency with which the various sites were attacked by dental caries exist between the natives of New Guinea and the white children of New Zealand.

(a) At the age of eleven years in New Zealand almost 100% of all first permanent molars show fissure lesions. In New Guinea in the age-groups 11-15, 5.4% of 148 first permanent molars showed fissure lesions (data from original records) and none had been lost. Indeed in this age-group the second permanent molars were affected more frequently than the first.

(b) In New Zealand children at fourteen years 50% of the distal surfaces of the central incisors and mesial surfaces of the lateral incisors were carious and 30% of the mesial surfaces of the central incisors were carious. On the other hand, up to the age of 15 years in New Guinea children there was only one lesion detected on these surfaces. In the next age-group, 16-29, two of 164 (1.2%) of the distal surfaces of the central incisors and one of 164 (0.6%) of the mesial surfaces of the lateral incisors were affected and none of the 164 mesial surfaces of the central incisors was affected.

(c) No carious lesions occurred in the lingual pit of the upper lateral incisors in any of the New Guinea natives, whereas in the white children at the age of 14 years approximately 28% of these pits were affected by caries.

(d) Table 29 shows the P : F : G ratio in the children of New Guinea and of New Zealand.

*Walsh, J. P. and Smart, R. S.—The relative susceptibility of tooth surfaces to dental caries and other comparative studies, N.Z.Dent.J., 44:17, 1948.

TABLE 29

Comparison of the P : F : G* Ratio per Ten Carious Surfaces in the Permanent Teeth of Children of New Guinea and of New Zealand.

		NEW GUINEA			NEW ZEALAND	
Group	Approx. Age (years)	Pātep II P : F : G	Kavataria P : F : G	Korovagi P : F : G	Age (years)	P : F : G
B	6–10	0 : 9 : 1	0 : 7.5 : 2.5	0 : 0 : 10	5–14	4.4 : 5.0 : 0.6
C	11–15	1.1 : 7.8 : 1.1	2.0 : 6.5 : 1.5	0 : 8 : 2		*

* P : F : G ratio = the proportion of proximal : fissure : gingival surfaces in permanent teeth attacked by caries.

Because the total number of affected surfaces in the New Guinea children was so small, a great deal of weight cannot be placed on these figures. For instance in Korovagi in the 6-10 age-group all the cavities occurred in one child. However the table does show in each village and age-group a much lower P : F ratio in the New Guinea group than in the New Zealand group.

D. Site of Election of Dental Caries in Deciduous Teeth.

From a study of tables 17 and 34 and figures 56-58, it appears that the condition of the deciduous teeth is atypical in several respects.

In the New Guinea children (and to a less extent in adults) the teeth were attacked by caries in sites different from those usually affected in Australian children. Instead of the pits and fissures of molars and approximal surfaces generally being first involved, the lesions were much more frequent on the upper incisors. In many cases these teeth were encircled in a "ringbarked" fashion or else the middle and gingival thirds were involved. Somewhat less frequently the deciduous molars were attacked by a similar type of lesion involving the cusps and/or buccal and lingual surfaces in an irregular fashion. The character of these lesions often suggested that the enamel of the cusp or ridge had been fractured and dislodged, exposing the dentine, which had subsequently become black, tough and leathery and therefore had to be regarded as carious. (Appendix C: Odontoclasia.)

In Kavataria caries is much more severe in the deciduous teeth than in the permanent; and the difference in the number of persons with only deciduous teeth affected by caries and the number of persons with only permanent teeth so affected is statistically significant ($\chi^2 = 4.88$).

E. Frequency of Attack upon Individual Teeth by Caries.

Why some teeth should be more prone than others to attack by caries is a question which is often asked. For white populations several observers[67, 68] have pointed out that it frequently occurs equally and symmetrically on both sides of the mouth. Some have pointed to a relative immunity possessed by the upper posterior teeth as compared to their lower antagonists[69]; others have found the reverse[68].

[67]Bertram, F. P. and Brown, J. E.—Phenomenon of bilateral dental caries: a statistical analysis, J.Amer.Dent.Ass., 30:1392, 1943.

[68]Scott, D. B.—A study of the bilateral incidence of carious lesions, J.Dent.Res., 23: 105, 1944.

[69]Klein, H. and Palmer, C. E.—Posteruptive tooth age and differences in the caries susceptibilities of the several permanent teeth, J.Dent.Res., 19:294, 1940.

Table 30 shows the frequency with which the individual teeth became carious in the young and middle-aged adults (approx. age 16-44 years) of Pātep II.

TABLE 30

Pātep II—Subjects aged 16–44 years.

Frequency of Attack of Individual Teeth by Caries (roots and missing teeth presumed to have been affected by caries included).

	Position of Teeth																
LEFT	8	7	6	5	4	3	2	1		1	2	3	4	5	6	7	8	RIGHT
Upper	15	10	5	2	0	0	6	11		5	5	2	1	1	2	9	19	
Lower	18	11	10	1	2	0	2	1		1	2	0	2	2	14	20	20	
	3RD MOLAR	2ND MOLAR	1ST MOLAR	2ND BICUSPID	1ST BICUSPID	CANINE	LATERAL INCISOR	CENTRAL INCISOR		CENTRAL INCISOR	LATERAL INCISOR	CANINE	1ST BICUSPID	2ND BICUSPID	1ST MOLAR	2ND MOLAR	3RD MOLAR	

It is seen that upper incisors were affected more often than lower, and that the lower molars were affected slightly more often than the upper. In each quadrant except the lower right the third molar was the most frequently affected tooth.

F. Bacteriology.

Approximately 750 strains of microorganisms were isolated and brought back for study in the Institute. Considerable time will be required before this large number of cultures can be identified. However, sufficient data have become available to justify conclusions that lactobacilli do occur in the mouth of New Guinea natives (Pātep II) and that some of these strains possess the power of lowering the hydrogen ion-concentration of glucose-broth to levels between 4.0 and 5.0; that Candida likewise occurs in the mouth of New Guinea natives and that gram-negative rods of the genus Bacterium are also present. The total number of persons examined at Pātep II was 136 but satisfactory clinical *and* bacteriological data are available for only 127 of these.

Lactobacillus.

1. *Distribution of subjects in relation to the presence or absence of Lactobacillus and/or caries.* Of 127 subjects for whom sufficient data are available, 36 showed the presence of lactobacilli in the one sample of saliva taken and 91 did not. 63 of the 127 had caries, but only 29 of the 63 had lactobacillus, a result which is broadly comparable to that reported by Enright, Friesell and Trescher[70]. Table 31 shows the relationship between the presence of Lactobacillus and of caries.

[70]Enright, J. J., Friesell, H. E. and Trescher, M. O.—Studies of the cause and nature of dental caries, J.Dent.Res., 12:759, 1932.

TABLE 31

The Relationship between the Presence of Lactobacillus and the Occurrence of Caries.

Group	No. of subjects	Lactobacillus	Caries
A	29	+	+
B	7	+	—
C	34	—	+
D	57	—	—

χ^2 (calculated from a fourfold table) = 19.25 : significant.

When the χ^2 rule is applied to these figures a value of 19.25 is obtained, which indicates a high degree of significance in the association between the existence of dental caries and the presence of Lactobacillus in samples of activated saliva.

2. *Distribution of carious teeth in relation to the presence or absence of Lactobacillus.* From the 29 persons in group (A) above, Lactobacillus was isolated and between them they had a total of 120 carious teeth or an average of 4.14 per person. From the 34 persons in group (C), Lactobacillus was not isolated and between them they had a total of 97 carious teeth or an average of 2.85 per person, i.e., only about two-thirds the average number in group (A).

3. *Distribution of carious surfaces in relation to the presence or absence of Lactobacillus.* The 29 persons in group (A) above between them had a total of 188 carious surfaces or an average of 6.48 per person. The 34 persons in group (C) between them had a total of 121 carious surfaces or an average of 3.56 per person. It would thus appear that of the 63 persons with dental caries, 29 who showed the presence of Lactobacillus had nearly twice as many carious surfaces as did those who failed to show the presence of Lactobacillus.

Statistical analysis of the figures given in paragraphs 2 and 3 above reveals: (a) a suggestive but not significant relationship between the number of standing carious teeth and the presence of Lactobacillus and (b) a significant relationship between the number of carious surfaces on standing teeth and the presence of Lactobacillus.

4. *Distribution of types of Lactobacillus (S.A. and W.A.*) in groups (A) and (B).* It was not possible to determine statistically any relationship between the presence or absence of caries and the occurrence of the two types (S.A. and W.A.) and Lactobacillus, because the numbers were too small.

Yeast-like organisms.

Although there had been no intention to search for yeast-like organisms ("yeasts"), in so far as these will grow on tomato-peptone agar, it was decided to study such strains as could easily be recognised on the plates. Forty-one of these, selected at random, were brought back to the Institute and have been investigated by Lilienthal & Goldsworthy[71, 72] and Lilienthal[73]. They showed that 28 out of 41 strains (68%) were typical Candida albicans, a proportion

*S.A. = strongly acidogenic; W.A. = weakly acidogenic[58].

[71]Lilienthal, B. and Goldsworthy, N. E.—Studies of the flora of the mouth, I, Yeast-like organisms: some morphological and physiological characters. In the Press.

[72]Lilienthal, B. and Goldsworthy, N. E.—Studies of the flora of the mouth, II, Yeast-like organisms: serological properties. In the Press.

[73]Lilienthal, B.—Studies of the flora of the mouth, III, Yeast-like organisms: some observations on their incidence in the mouth. In the Press.

of Candida albicans comparable to that which can be isolated in civilised communities.

When the presence or absence of "yeasts" is examined in relation to the presence or absence of caries, no statistically significant association is revealed (table 32).

TABLE 32

The Relationship between the Presence of "Yeasts" and the Occurrence of Caries.

Group	No. of subjects	"Yeasts"	Caries
A	32	+	+
B	31	+	—
C	31	—	+
D	34	—	—

χ^2 (calculated from a fourfold table) = 0.11 : not significant.

Similarly it was shown that no significant relationship existed between the occurrence of "yeasts" and that of Lactobacillus and accordingly none between the joint occurrence of "yeasts" and Lactobacillus and the occurrence of caries. Lastly, of 134 subjects examined for the presence of "yeasts" at least 59 (44%) yielded evidence of their presence.

Gram-negative rods (especially Aerobacter aerogenes).

Over 100 strains are being examined in the Institute, but unfortunately the investigation has not been completed. The object of the investigation of these gram-negative rods is to determine whether ammonia-producing strains of the genus Bacterium were present and whether their presence bore a significant relationship to the absence of dental caries, as suggested by Kesel[74] and others.

G. Fluorine in Drinking Water.

Owing to the wide interest now being manifest in the relationship between the ingestion of fluorine (particularly in drinking water) and the lowering of the incidence of dental caries, the opportunity was taken to bring back for analysis a few samples of the water used by the native population for cooking and drinking purposes. These were analysed as part of a large series of domestic waters most of which came from N.S.W. In no instance was more than 0.45 part per million detected. (Jones[75]) (Appendix A.)

H. Dietary Pattern and Food Habits.

(a) *General Pattern.*

The methods used in collecting these data are described elsewhere.

The native peoples investigated lived in settled communities. They ate cultivated foodstuffs, supplemented by 'wild' foods collected from the surrounding countryside. The amount of cultivated food was least at Korovagi where the staple, sago, was obtained from the palms which grew wild in the neighbouring swamps.

[74]Kesel, R. G., O'Donnell, J. F., Kirch, E. R. and Wach, E. C.—Ammonia production in the oral cavity and the use of ammonium salts for the control of dental caries, Amer.J.Orthod.Oral Surg., 33, Oral Surg., 80, 1947.

[75]Jones, Pamela B.—The fluorine content and other chemical characteristics of potable waters in N.S.W., Dent.J.Aust., 21:231, 1949.

Staple foods. In Pātep II the staple foods were taro and sweet potato and the supplementary items consisted of green leaves and various other vegetables and fruits. Animal protein was consumed only at feasts, one of which was held during the month of the Survey party's visit: on this basis the average consumption was 0.1 ounce of pig flesh per person per day. Small opossums and rats were trapped, but were dried and stored and eaten only at irregular intervals.

Yams were the staple food at Kavataria, supplemented fairly extensively by fish, crabs and shellfish; less often by taro, sweet potato, bananas, coconuts and paw paw. These people ate very few green leaves.

At Korovagi sago was supplemented with, and at some seasons replaced by, sweet potato, taro and pumpkin. Bananas, coconuts, breadfruit and corn were also popular and many varieties of bush fruits, nuts and green leaves were collected in season. Fish was eaten fairly frequently, grubs and shellfish occasionally; pig and crocodile meat were rare delicacies.

Fluids. Domestic water came from mountain streams at Pātep II, springs in the coral at Kavataria and a well near the river at Korovagi. The main fluid drunk was that used for cooking (as soup) and the milk of green coconuts; the natives' daily intake appears to be less than that of the Europeans in the same environment. Campbell[33] (*loc. cit.*, p. 80), discusses a similarly low intake by Australian aborigines as compatible with the maintenance of physiological efficiency.

Cooking methods. The cooking was done indoors at Pātep II and in the open at Kavataria and Korovagi. The two main items of 'kitchen' equipment were a cooking pot made of clay, bamboo (Pātep only) or metal and a European knife.

Vegetables were usually boiled but occasionally were baked in their skins. In Pātep II staple and greens were boiled separately in vessels with lids of leaves or grass.

At Kavataria hotter fires and less water were used and the vessels were lined and covered with leaves, which were not usually eaten but chosen for their flavour. The liquid was consumed as soup. Coconut oil was added to a number of cooked dishes. Fish were boiled with yams or wrapped in green leaves and baked. Shellfish and crabs were added to the pot or roasted.

Almost all the food at Korovagi was consumed as soup made with sago as a base; the other items mentioned were added. The cooking-vessel was used without a lid.

Raw foods. In each village various kinds of fruit and vegetables were eaten raw. Some were only seasonal, others scarce and considered as delicacies, but they almost certainly contributed qualitatively to the diet.

Times of Eating. Generally only one substantial meal was eaten and this at the end of each day (except at Pātep II where there was often a cooked breakfast); other food was taken at irregular intervals either raw or as residues from the main (cooked) meal.

Infant feeding. All children were breast-fed for 12 to 18 months and this time was often extended. Supplementary feeding began at about three months and even earlier in Korovagi. In Pātep II and Kavataria premasticated taro and in Korovagi clear sago soup were introduced first. Coconut was the last food to be given.

(b) *Evidence (dietetic, biochemical and clinical) on the consumption of specific nutrients and on possible requirements.*

Figures of the National Research Council, U.S.A.[76] have been taken as a standard of possible nutritional requirements but allowance has been made in some cases for the physique and activity of the New Guinea peoples[42].

Calories. In Pātep II and Kavataria the natives appeared on medical grounds to have an adequate calorific intake, but not so in Korovagi.

Protein. The intake of protein was low in all three villages, even in Kavataria where fish and shellfish were abundant. Apart from such foods practically all protein was of vegetable origin. (Lack of animal protein has more serious consequences for children than for adults.)

Calcium. Most of the calcium came from green leaves, which often contain as well some oxalic acid which decreases the availability of calcium. Owing to the bulk of such foods, the inferior availability of vegetable calcium and the lack of milk, the intake particularly in children appeared to be too low.

Vitmin D. Clinical and radiographical evidence revealed only a negligible incidence of rickets, so that despite the apparent lack of calcium no permanent damage to bone structures is suffered. It is therefore concluded that there is no deficiency of vitamin D in the diet.

Ascorbic acid and thiamin. The intake of ascorbic acid and thiamin appeared to be above normal computed requirements.

Vitamin A, riboflavin and niacin. No clinical evidence of a deficiency of vitamin A, riboflavin or niacin in the diet was detected.

Iron and iodine. There was no clinical evidence of a deficiency of iron—or of iodine-intake.

(c) *Physical nature of the diet.*

We are unable to give quantitative data on the physical nature of the foods eaten by the New Guinea peoples but the following remarks may be permissible:

Cooked taro had a somewhat waxy texture; yams were dry and fibrous; sweet potatoes were rather firm and baked sago sticks were gelatinous on the outside and crumbly inside. Children frequently ate the tough, fibrous flesh of ripe coconuts, which was also shredded and added to various dishes. The crisp, spongy endosperm of sprouting coconuts was popular among the children of Korovagi. Sugar cane, which is very fibrous, was chewed by many of the natives. It seems, therefore, that foods eaten by the New Guinea natives have a wide range of variation in texture, as have our own, *e.g.*, from that of mashed potatoes to that of fresh apples.

However, green leaves when cooked were quite soft and in Korovagi practically all food was consumed in the form of a soup.

It is noteworthy that the natives lacked entirely any foods which are refined and purified to the degree which characterises our white flour and sugar.

Fruit was usually eaten raw, whereas among civilised peoples much is eaten cooked.

Another difference then, observed between the habits of the native and those of the European, is in the manner of eating and the wider range of tasks which his teeth perform. The native places in his mouth large pieces of food or bites a big mouthful as, *e.g.*, from a tuber sago stick; whereas the European is accustomed to taking food cut into small pieces. The native's teeth are also

[76]National Research Council, Food Nutrition Board, U.S.A.—Recommended dietary allowances, Rept. & Circ., Ser. No. 129, 1943.

put to a wide variety of other uses (stripping sugar cane prior to chewing; holding a variety of articles).

The main difference, then, between the general diet of the New Guinea people as a whole and white people in urbanised societies lay in the complete absence of soft, sweet food made from refined (denatured) ingredients (*e.g.*, white flour and white sugar).

TABLE 33

Comparison of the Incidence of Caries in the Three Villages, each considered as a unit.

Village	% people * with caries	% teeth carious	mean % surfaces carious
Pātep II	52.34	6.32	1.73
Kavataria	42.86	4.51	1.20
Korovagi	30.00	2.70	0.64

* Calculated on the basis of 128, 91 and 100 subjects in Pātep II, Kavataria and Korovagi respectively.

DISCUSSION.

A. Incidence and Distribution of Carious Lesions.

(a) Comparison of the three villages each considered as a unit. On examination of the results it appears that irrespective of the basis (whether *persons* or *teeth* or *surfaces*) for assessment of the severity and extent of the carious process, the disease is most prevalent in Pātep II, less so in Kavataria and least in Korovagi (table 33).

Statistical analysis of the figures on the basis of people with or without caries shows that the differences between (i) Pātep II and Korovagi ($\Sigma\chi^2 = 31.23$), (ii) Pātep II and Kavataria ($\Sigma\chi^2 = 40.76$) and (iii) Korovagi and Kavataria ($\Sigma\chi^2 = 14.74$) are significant.*

(b) Comparison of the different incidences of caries in the different age-groups in each of the three villages. On whatever basis the incidence is determined (persons or teeth or surfaces), in Pātep II it increases with age. On the other hand in Kavataria the children seem to suffer from dental caries far more than do the adults. In Korovagi the intensity of the carious process seems to be about the same for all age-groups. Table 34 shows these different

TABLE 34

Percentages of Carious Teeth in the Different Age-Groups in Each Village. (Numbers are given in tables 16–25.)

Group	Approx. Age (years)	Percentages of carious teeth		
		Pātep II	Kavataria	Korovagi
A	1–5	2.61	20.13	3.57
B	6–10	6.91	15.36	6.87
C	11–15	2.11	5.04	2.86
D	16–29	5.04	0.83	1.91
E	30–44	8.44	0.62	1.88
F	45 and over	14.54	2.32	0.72
	Totals	6.32	4.51	2.70

*These analyses were made by age-groups and the significance determined by summation of χ^2 values for the six individual groups. However, the difference between Kavataria and Korovagi is rendered significant only by the large difference between the B Groups in the two villages.

distributions on the basis of percentage of carious teeth.

(c) Comparison of the different incidence of caries in deciduous and permanent teeth. The difference in the degree to which deciduous and permanent teeth are affected in any one village can best be shown statistically when *numbers of persons* rather than of teeth are compared.

(1) Within each village (Tables 16A-18A): at Pātep II the number of persons who had caries was significantly higher among those with only permanent teeth (61.54%) than it was among those with only deciduous teeth (21.74%) ($\chi^2 = 11.69$). When a similar comparison is made for Kavataria significantly more people had caries of the deciduous teeth (62.5% deciduous and 24.56% permanent) ($\chi^2 = 4.88$). In Korovagi there was no significant difference ($\chi^2 = 0.20$).

(2) Between the villages: when the populations have been divided into those with deciduous and those with permanent teeth, it becomes possible to compare the number of persons with or without caries in each village on two distinct bases:

(i) that portion of the whole population with only permanent teeth;

(ii) that portion of the whole population with only deciduous teeth.

Analysing and comparing the figures for 'permanent groups' only it is seen that far more of these people suffer from caries in Pātep II than in Kavataria or Korovagi. Of the children with only deciduous teeth, more suffer from caries in Kavataria than in Pātep II.

Tabulation of the incidence (people with or without caries) reveals the 'order of merit' shown in table 35. It should be noted that the term 'bad' is used for comparison only between the three villages; by comparison with those of civilised peoples the teeth of the New Guinea people are good.

B. THE PROBABLE CAUSES OF MISSING TEETH.

(a) Removal by the natives themselves: as far as we were able to ascertain, the natives living in the areas visited do not indulge in any religious practices involving tooth-mutilation or extraction; nor do they, as far as we know, remove their teeth to relieve pain except when periodontal disease has weakened the bony support and the tooth becomes troublesome and loose.

(b) Removal by Europeans: in only two instances did we obtain a history of extractions by Europeans. In each the subject was an inhabitant of Korovagi and had had the extractions performed during some former period of service as indentured labour. The people of Pātep II had had little contact with white

TABLE 35

Caries Incidence (people with or without caries) expressed as an "order of merit."

Village	all teeth	"permanent" group	"deciduous" group
Pātep II	4 (bad)	5 (very bad)	1 (very good)
Kavataria	3 (moderate)	1 (very good)	5 (very bad)
Korovagi	2 (good)	2 (good)	3 (moderate)

people and their geographical position makes it unlikely that they had ever received this dental service. Kavataria on the other hand was only a mile away from the native hospital at Losuia, although hospital records showed that extractions done were almost always for natives from villages farther inland than Kavataria.

(c) Absence for other reasons: in evaluating likely reasons for the absence of a tooth or its crown the following possibilities were considered—caries, periodontal disease, trauma, retarded eruption and congenital defect. Roots and missing teeth were placed in one or other category after consideration of—

i. the state of remaining teeth as regards caries;

ii. the condition of the periodontal tissues and firmness of the remaining teeth;

iii. the history given by the subject (although this was usually a matter of signs and broken phrases).

It is comparatively easy to understand how a tooth can be exfoliated when its bony support has disappeared (figs. 48 and 49). That the entire tooth can be destroyed by a carious process alone is a little harder to understand but some of the radiograms present evidence which indicates that this can and does occur (fig. 54).

Tables 36-38 give the number of missing teeth in each age-group and the probable cause thereof and show the following trends:

(i) the mean number of missing teeth per head of population (all causes) is 2.27 in Pātep II, 2.30 in Kavataria and 0.65 in Korovagi. However, the lower number of missing teeth in Korovagi may be partly due to the fact that fewer of the oldest subjects presented themselves for examination.

(ii) tooth-loss increases with age, irrespective of the cause, in all three villages. In each village the number of missing teeth in the group of young adults (aged 16-29 years) is somewhat higher than it would be if the figure included only pathological and traumatic causes, because some of these subjects had unerupted third molars, which are included among the number of missing teeth.

(iii) the relatively large number of teeth which seemed to have been lost by caries in Pātep II is indicated by the carious condition of many of the remaining teeth.

(iv) although in Kavataria caries or odontoclasia was very prevalent in deciduous teeth, it obviously did not cause premature loss of such teeth. Acute periapical conditions of affected deciduous teeth were very rarely observed.

C. Relationship between Caries and Periodontitis.

An inverse relationship between the incidence of these two diseases has frequently been reported in the literature (Section VI).

TABLE 36
PĀTEP II
Classification of Probable Causes of Missing Teeth

Group	Approx. Age (years)	Total No. subjects examined	No. teeth standing	Total No. missing teeth + roots	No. missing teeth or roots per person	Number of teeth missing and probable cause						Number of roots and probable cause		
						caries	perio-dontitis	trauma	un-erupted	congeni-tally absent	unknown	caries	trauma	unknown
A	1–5	23	460	0	0	0	0	0	0	0	0	0	0	0
B	6–10	14	333	1*	0.07	0	0	0	0	0	0	1	0	0
C	11–15	12	332	2	0.17	0	0	0	0	1	1	0	0	0
D	16–29	46	1408	67	1.46	3	0	0	19	14	3	24	4	0
E	30–44	23	675	62	2.70	22	5	1	1	2	5	20	6	0
F	45 and over	18	399	177	9.83	48	5	0	0	0	3	121	0	0
Totals		136	3607	309	2.27	73	10	1	20	17	12	166	10	0

* The loss of the crown of this tooth was regarded as the result of caries.
(Teeth presumed unerupted are excluded from consideration for the first three age-groups.)

TABLE 37

KAVATARIA

Classification of Probable Causes of Missing Teeth.

Group	Approx. Age (years)	Total No. subjects examined	No. teeth standing	Total No. missing teeth + roots	No. missing teeth or roots per person	Number of teeth missing and probable cause						Number of roots and probable cause		
						caries	perio-dontitis	trauma	un-erupted	congenit-ally absent	unknown	caries	trauma	unknown
A	1–5	8	159	1	0.13	0	0	0	0	0	0	1	0	0
B	6–10	13	306	0	0	0	0	0	0	0	0	0	0	0
C	11–15	13	357	2	0.15	1	0	0	0	1	0	0	0	0
D	16–29	19	602	6	0.32	0	0	0	5	0	1	0	0	0
E	30–44	26	804	28	1.08	0	6	2	0	4	14	2	0	0
F	45 and over	15	301	179	11.93	2	64	0	0	1	103	5	0	4
	Totals	94	2529	216	2.39	3	70	2	5	6	118	8	0	4

(Teeth presumed unerupted are excluded from consideration for the first three age-groups).

TABLE 38

KOROVAGI

Classification of Probable Causes of Missing Teeth.

Group	Approx. Age (years)	Total No. subjects examined	No. teeth standing	Total No. missing teeth + roots	No. missing teeth or roots per person	Number of teeth missing and probable cause						Number of roots and probable cause		
						caries	perio-dontitis	trauma	un-erupted	congenit-ally absent	unknown	caries	trauma	unknown
A	1–5	9	168	0	0	0	0	0	0	0	0	0	0	0
B	6–10	19	451	2	0.11	2	0	0	0	0	0	0	0	0
C	11–15	10	280	0	0	0	0	0	0	0	0	0	0	0
D	16–29	17	528	20	1.16	0	2	2	10	2	4	0	0	0
E	30–44	32	1013	11	0.34	2	2	2	5	0	0	0	0	0
F	45 and over	14	416	33	2.36	4	27	1	0	0	0	1	0	0
	Totals	101	2856	66	0.65	8	31	5	15	2	4	1	0	0

(Teeth presumed unerupted are excluded from consideration for the first three age-groups.)

The results show that in those over 30 years of age the combination occurring most frequently in Pātep II is a Caries Index of 0-4% (surfaces of standing teeth) and a mild degree of periodontitis. In Kavataria it is more frequently a Caries Index of 0.0 with an advanced degree of periodontitis. In Korovagi the commonest condition is a Caries Index of 0.0 with a mild or advanced degree of periodontitis. These results suggest a mutually exclusive relationship but it should be remembered that the number of subjects is small.

D. Relationship between Caries and Attrition.

(a) *Occlusal attrition.* The occlusal surfaces of, for example, permanent molars usually present one or more pits or fissures which are difficult or impossible to clean (by natural or artificial methods), thus providing a suitable environment for the initiation of a carious lesion. If the diet and nature of the saliva are such as to produce a high susceptibility to dental caries in the dentition as a whole, the lesion rapidly increases in size and, unless restorative measures are undertaken, leads to infection and death of the dental pulp regardless of whether attrition is taking place or not. On the other hand, when the caries-producing factors are somewhat less active and the lesion is progressing very slowly, if attrition takes place on the occlusal surface, it may 'overtake' the carious process and the pit and underlying carious dentine will be 'ground out', leaving a smooth surface which is then less susceptible to caries.

In Pātep II the carious process must have been sufficiently rapid to be unaffected by attrition, because in the adults the occlusal pits were often obviously carious and a number of teeth were missing (presumably due to caries). On the other hand in Kavataria and Korovagi the carious process was slower, so that in the older people the occlusal surfaces of the molars were worn smooth and showed caries of only the same or even of a less frequency than in the young people. However, in addition to any difference in the severity of carious attack (generally speaking it was less in Kavataria and Korovagi than Pātep II) the teeth of the natives of Pātep II showed less attrition than those of the same age-group in Kavataria and Korovagi (table 6).

(b) *Approximal attrition.* In a child or young adult the most frequent type of contact is that where the approximating surfaces of the teeth are spheroidal and so are in contact over only a minimal area. This is usually considered to be the kind of contact which is least susceptible to dental caries; and in certain cases, when the teeth do not have this form, procedures such as discing (Black)[51] (*loc. cit.*, vol. iv, p. 122) have been suggested to reduce the size of the contact-area and widen the embrasures to facilitate cleaning the tooth-surface. As age advances, attrition takes place approximally and the area of contact of the teeth become broader and flatter, which Black[51] (*loc. cit.*, vol. iv, p. 121) maintains increases the susceptibility to dental caries. The classical treatment suggested is the placement in the teeth of mesial and distal restorations with contours similar to those seen in a young person.

On the other hand, there are reasons why approximal attrition should rather lessen the susceptibility of these surfaces to caries. In white people, when caries is seen approximally, it occurs usually just below the contact-point, which would seem to indicate that the contact-point itself is caries-immune This is probably because (when hard food is eaten) the two teeth rubbing together are mutually self-cleansing. The more the two teeth rub together the greater should be the degree of immunity and also, as attrition takes place, the greater should be the area of enamel protected by this immunity.

Although some degree of approximal attrition appears to have taken place in almost all the adults in New Guinea (and some models of older people show it to have occurred to a very advanced degree) it does not appear to have increased the susceptibility of these approximating surfaces to dental caries, as its incidence on these surfaces (and indeed in the mouth as a whole) was very low. The possible exceptions would be in the over 45 age-group at Pātep II, where the incidence of lesions on approximal surfaces equalled 2.7 per person; but most of these lesions were apparently initiated at the cemento-enamel junction (fig. 55).

E. Relationship between Caries and Oral Flora.

The aetiology of dental caries cannot be discussed adequately without reference to possible bacteriological factors. Even those who support the view that such factors as diet, nutrition, heredity, are dominant in the aetiology are probably prepared to admit, if somewhat grudgingly, the possibility that micro-organisms play a part. We ourselves see no reason for precipitately abandoning the traditional viewpoint commonly attributed to Miller[77], and it was largely to determine whether the oral conditions would support or refute this hypothesis that our investigations in New Guinea were undertaken.

[77]Miller, W. D.—The micro-organisms of the human mouth, Philadelphia, 1890.

Of the bacteria most commonly implicated the *Lactobacillus* has received greatest attention. The general aim of our investigations was, therefore, to determine the presence or absence of lactobacilli in the mouths of New Guinea natives and to correlate, where possible, such presence or absence of lactobacilli with the presence or absence of dental caries. In attempting to define any relationship between the presence of dental caries and the presence of Lactobacillus among the oral flora it is felt that the ratio of the number of standing carious surfaces to the total number of standing surfaces in the mouth should be used as an indication of the existing activity of the disease.

The results obtained appear to leave no doubt as to the existence of a significant degree of association between the presence of Lactobacillus and the presence of dental caries: an association which, however, does not prove the existence of an ætiological relationship. It is, nevertheless, interesting that a relatively isolated population has yielded confirmatory evidence of the association of Lactobacillus with caries. That the association has not been proven to be even closer is probably due to our inability to make more than one examination of the subjects, although Harrison[78] found Lactobacillus in cultures from only three of ten carious teeth; and from material from carious areas lactobacilli were recovered from only 51%: results which are interpreted by Harrison as indicating that the Lactobacillus is not as important as many claim it to be.

However, further support for the significance of this association may possibly be seen in the greater average number of standing carious teeth and standing carious surfaces per person in those persons who (i) have Lactobacillus than in those who (ii) have no Lactobacillus.

Frequently associated with Lactobacillus are various *'yeast-like' organisms ("yeasts")*, mainly Candida. These, too, but only secondarily, we sought to detect and study. No satisfactory claim has been made that "yeasts" are principal aetiological agents in caries, but evidence has been advanced by Fosdick[79] and by Lilienthal[80] that the synergistic activities of "yeasts" and Lactobacilli result in enhanced acidogenesis; the implication being that such synergistic activity might more effectively initiate and promote caries. Our results do not support this implication, because among 30 persons with caries *and* Lactobacilli 15 had "yeasts" and 15 did not; also among 30 persons with caries and no Lactobaccilli 17 had "yeasts" and 13 did not.

In another series of observations, however, where C. albicans alone among the "yeasts" was considered a significant relationship between the occurrence of Lactobacillus and C. albicans was established (Lilienthal[73]).

Recently another group of organisms, *gram-negative rods* such as Aerobacter aerogenes, has been studied (Kesel *et al.*[74]) and it has been suggested that they inhibit the growth of Lactobacilli and the conversion of glucose to acid. The strains recovered in New Guinea have not yet been examined and identified.

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[78]Harrison, R. W.—Lactobacilli versus streptococci in the aetiology of dental caries, J.Amer.Dent.Ass., 37:391, 1948.

[79]Fosdick, L. S.—The phosphatase activity of various mouth organisms, Northwest Univ.Bull., 37:23, 1937.

[80]Lilienthal, B.—Studies of the flora of the mouth, IV. Some observations on acid-production by lactobacilli and Candida albicans: a preliminary report. In the Press.

F. Relationship between Caries and Diet.

As many writers (*e.g.*, Rosebury[81]) have pointed out, dental caries does appear to be in some indefinable way related to civilisation, not so much because of the nature of civilisation in the more commonplace and restricted meaning of this term as because of the concomitant dietary and food-habits. Several investigations of this aspect of the problem may be mentioned, particularly that of Campbell[33], who studies the aboriginal inhabitants of Australia. He made a survey of the teeth of aboriginal skulls and living subjects and published figures which showed a very low incidence of caries. His figures for living subjects refer to a mixed group of natives having various degrees of intimacy of contact with western civilisation. The evidence obtained from examination of the skulls would suggest that the incidence among natives in their entirely natural state was even lower than in the living subjects. Furthermore, in general, the incidence of dental caries was greatest in the senescent period of life and almost non-existent in the children and adolescents. This contrasts sharply with the position among civilised white people in Australia, where the prevalence approaches 100% and the activity is greatest in the age-groups from 5-15 years.

Campbell[33] has also investigated the food-habits of the people he examined and has published extensive data to this effect, viz., (i) the aborigines live a nomadic life forced upon them by the arid nature of the country they inhabit and the low level of its food-productivity; (ii) they eat anything which is edible, with a preference for animal flesh; (iii) food is given very little or no preparation and cooking, so that it loses a minimum of its nutritional value; (iv) the nature of the food and of its preparation means that the aborigines are compelled to use their masticatory apparatus far more than are civilised peoples, because their food is tough, fibrous and mixed with sand and ashes; (v) owing to the nature of the food and the feeding-habits of the aborigines the masticatory apparatus is in use for a considerable part of the day; (vi) quantitatively the food may not always be adequate but qualitatively it probably leaves little to be desired, because of its variety and minimum of preparation and cooking; (vii) despite lack of mammalian milk other than human, calcium is probably more than adequate during the first few years of life because of the prolonged period of breast-feeding; (viii) vitamin D is also probably adequate because, despite pigmented skin, there is prolonged exposure of the almost naked body to actinic rays.

Campbell's [4, 33] publications also show that the degree of intimacy of contact with civilisation is reflected in the degree to which the teeth are affected by caries. Restarki[82] made observations on pure blooded Samoans and likewise observed that the teeth of the children in villages near the U.S. Naval Station were much more affected than the teeth of children in the outlying villages. Hartmann[83] investigated the teeth of children in Micronesia, observing two ancestrally distinct groups on the island of Yap; he suggested that the higher incidence among the Chamorro group may be the result of the inclusion of more

[81]Rosebury, T.—The problem of dental caries, Dental Science and Dental Art, ed. by Gordon, S. M., Philadelphia, Chap. VIII, p.269, 1938.

[82]Restarki, J. S.—Incidence of dental caries among pure-blooded Samoans, Nav.Med. Bull.Wash., 41:1713, 1943.

[83]Hartmann, F. W.—Prevalence of dental caries in two groups of children in Micronesia, J.Amer.Dent.Ass., 35:753, 1947.

carbohydrates (bread and rice) in the daily diet. Klatsky[29, 84] studied the dietary of contemporary primitive peoples; he considered it wrong to hold that dental abnormalities and the incidence of caries among civilised people are caused mainly by nutritional deficiencies and that it is also wrong to ascribe large jaw bones and comparatively healthy teeth to superior nutrition. He investigated particularly the physical or textural characteristics of the diet and emphasised the relatively monotonous and restricted nature of the diet of the uncivilised. He examined 4000 skulls of 46 different racial stocks, both primitive and civilised: not a single carious tooth was found among 3077 teeth (337 skulls) of British Columbia primitives or among 1974 teeth (255 skulls) of Eskimos. His comments on the mode of preparation, cooking and eating show that the dietary habits of these primitives were similar to those of the Australian aborigines.

Denston[85] examined a composite group of aborigines in the Northern Territory of Australia, 1302 persons in all, of whom 805 were males and 497 females. They included persons who had had widely different degrees of contact with white people, their ways of life and their food-habits. Denston found that 54% of the whole group (including a few half-castes) were free from dental caries. This percentage (54%) is roughly comparable to the percentage of caries-free people in the three New Guinea villages visited.

Many other reports have been published on the dental conditions and dietetic habits of groups of indigenous populations, *e.g.*, by Shourie[86], McIntosh[87], Weston Price[7], Pickerill[88] (*loc. cit.*, p. 247) Mummery[89], Day and Tandan[23] and Day[90].

Because diet, nutrition and health are so closely connected it seems pertinent to examine our data on dental conditions against the background provided by (i) the general physical development, health and nutritional status; (ii) the diet and (iii) the socio-economic organisation, including and especially the type of agronomy, of the people studied[42].

Admittedly it is not possible to establish any unequivocal relationship between caries and many of the subjects mentioned, but it is felt that these should be included in order to reveal, as fully as the data and space will allow, the broad outlines of the physical environment of the people and their dental apparatus.

(i) General Physical Development, Health and Nutritional Status [42]. (a) Physique and physical activity. The stature or body-build is on the whole smaller than that of Australians of Caucasian stock, but it is by no means certain what determines this difference—whether principally heredity or the apparent deficiency of protein-intake. Muscular development is often below average according to our standards, as also is the physical activity of the people.

[84]Klatsky, M. and Klatell, J. S.—Anthropological studies in dental caries, J.Dent.Res., 22:267, 1943.

[85]Denston, C. S.—Observations and conclusions drawn from a dental survey conducted on Australian Aborigines of the Northern Territory, Commonwealth of Australia, Department of the Army, 1944.

[86]Shourie, K. L.—Variation in diet and incidence of dental caries in India, J.Dent.Res., 26:446, 1947.

[87]McIntosh, W. G.—Dental studies and nutritional findings in the James Bay Indian, J.Canad.Dent.Ass., 15:69, 1949.

[88]Pickerill, H. P.—The prevention of dental caries and oral sepsis, London, 1912.

[89]Mummery, C. F.—Teeth of the Che Wong, Brit.Dent.J., 84:69, 1948.

[90]Day, C. D. M.—Nutritional deficiencies and dental caries in northern India, Brit.Dent.J., 76:115, 1944.

However, in themselves these differences appear to have little if any bearing on dental caries.

(b) Health. Malaria was the most serious threat to health in that it produced anaemia and "appreciably affected the nutritional status." Hookworm infestation, although widespread, was not heavy. Many conditions among civilised people were apparently almost unknown, *e.g.*, appendicitis, constipation, cholelithiasis, atherosclerosis and eclampsia. On the other hand, yaws was very widespread.

(c) Nutritional status (the physiological sufficiency of the people in relation to their particular environment). Knowledge of the physiology of the human body is largely based on data for people of Caucasian origin living in temperate or cool climates. Nevertheless it was rather surprising to observe that the natives had attained an apparently satisfactory equilibrium with their physical environment, despite what was by our standards to be regarded as a suboptimal or even dangerously unbalanced diet—this too even when due consideration was given to their more leisurely ways of living[91]. That relative freedom from dental caries should coexist with an allegedly defective nutritional pattern is not unexpected, because there are several reports of this seeming paradox[23, 36, 90, 92, 93, 94, 95].*

(ii) Diet. (a) Source and type of food. A lengthy discussion of these items would be both wearisome and inappropriate here. Sufficient it is to say that in general the natives' food was the produce of their gardens supplemented by wild berries, nuts and greenstuffs and by such scanty game as the land and sea would yield.

* But before we dogmatise that a diet or the resulting nutritional status is defective we should remember that there is no proof that all human beings possess an identical physiological ensemble —one man's bodily economy may permit him to attain and maintain physical efficiency within his own environment at a nutritional level which would be inadequate for another's needs. "The utility of a science of nutrition is predicated on the base that the nutrition of an organism is part of its environment and hence an understanding of the facts of nutrition leads facilely to a control of biologic events in which the organism participates." Nutrition must operate in a genotype and, if genotypes vary, as they do, then sometime or other the science of nutrition must come to grips with the problem of genotypes. There must be diversity of effects of a given nutrient as it operates in diverse genetic circumstances (Clark et al. [96], loc. cit. p. 104, Anon. [97], Williams et al. [98]). Hence what may seem an inadequate blood-level of vitamin C, serum albumin, haemoglobin, etc., for the Caucasian may not be such for the negroid.

This concept of genotypic influences exerted on the value of specific nutrients obviously introduces considerable difficulty into the definition of the nutritional requirements of different races and even of different individuals of one race.

It would therefore be rash to seek in diverse races too close a parallel between the evidence of good nutrition or between nutritional requirements for special purposes such as the development and maintenance of sound teeth. The same applies when the background of constitutional disease is different, as for instance as between the indigenous inhabitants of Europe and those of Central Africa.

[91] Sinclair, H. M.—The assessment of human nutriture, Vitamins and Hormones, New York, vol. VI, p.101, 1948.

[92] Reid, F. R.—Personal communication.

[93] Dreizen, S., Mann, A. W., Spies, T. D. and Skinner, T. A.—Prevalence of dental caries in malnourished children. A clinical study, Amer.J.Dis.Child., 74:265, 1947.

[94] Anonymous—Dental caries experience in malounrished children, Nutr.Rev., 6: 155, 1948.

[95] Bunting, R. W.—Report of the Michigan group researches on dental caries. Berichte erstattet am IX. Internationalen Zahnætzekongress der F.D.I., Erster Band, 1. Hælfte, Sektion IV, 332, 1936.

[96] Clark, P. F., McClung, L. S., Pinkerton, H., Price, W. H., Schneider, H. W. and Trager, W.—Influence of nutrition in experimental infection, Bact. Rev., 13:99, 1949.

[97] Anonymous—Relation of inheritance to nutritional requirement, Nutr.Rev., 5: 237, 1947.

[98] Williams, R. J., Berry, L. J. and Beerstechen, E.—Biochemical individuality, III, Genotrophic factors in the etiology of alcoholism, Arch.Biochem., 23:274, 1949.

The type of food was therefore largely vegetable, *i.e.*, largely carbohydrate in composition; but the carbohydrate was in a natural or near-natural state and *not* refined as is so much of ours.

(b) Preparation of food. Owing to the primitive economy of the natives there were but two means of denaturing their food-stuffs—storage and cooking. In general storage as we understand it was seldom practised; the cooking was not prolonged nor was the cooking-water discarded, but rather used as a soup.

(c) Physical characteristics of food as consumed. There have been many advocates for the view that tough, fibrous foodstuffs are necessary for the growth and maintenance of a strong healthy masticatory apparatus and, while the evidence adduced in support of this view is frequently attractive, it is impossible to ignore the arguments advanced by its opponents (Pickerill[88] (*loc. cit.*, p. 251); Weston Price[19]). One serious difficulty attendant upon any discussion of the effects of the so-called detergent diet is the absence of any precise data on the quantitative aspects of the physical nature of foodstuffs. In this respect the most outstanding difference between the diet of New Guinea natives and our own is the absence of white (refined) flour and sugar. The exclusive use of food derived from indigenous vegetation and game and its consumption in a relatively fresh and unchanged state provide the natives with a diet adequate for their nutritional needs, at least as far as these needs concern the maintenance of sound teeth.

(iii) Economic Background, especially Agronomy. In general the economic system is largely limited to agriculture supplemented in various degrees (according to climate and physical conditions) by the collection of wild foodstuffs.

Livestock play but little part in the methods of using the land and therefore contribute little, if anything, to the diet.

The methods of cultivation are simple but not unsystematic. The most important point in the system is the production of a staple foodstuff, invariably a starchy vegetable like sweet potato, taro, sago or banana.

Land may be communal but is invariably cultivated in small parcels by individuals whose personal rights to its use are widely recognised.

The long-fallow system prevails and no fertilisers are used. Where rain-forests and swampy lowlands prevail, collection of Nature's gifts tends to replace or limit cultivation, which is at its most intensive development in the cool high plateaux, *e.g.*, Pâtep II. Climate and geographical features make agriculture a difficult business and any production of food is to be regarded as an achievement.

In general, decreasing fertility of the land is to be expected. Improvements in agriculture may be difficult to introduce because of the conservative socio-religious basis for so many of the practices associated with the present system of cultivation.

In summary, we may say that the people of the three villages visited were of only medium physique and suffered fairly extensively from malaria and yaws. They practised a primitive and rather wasteful form of agriculture, calculated (in the climatic and geographical circumstances obtaining in New Guinea) to decrease the soil's fertility. The staple foodstuff was invariably a starchy vegetable and the diet was rather monotonous and to us insipid. Even after making allowances for local conditions their intake of nutrients was below the National Research Council's recommended allowances in many respects (but above them in others). Animal protein was available in only small quantities

and often not at all. The physical nature of the diet was in general fibrous but not tough, and staples such as taro required only average use of the masticatory apparatus. No refined or prepared foodstuffs were used.

It is not possible to relate the dental conditions as reported above with any single circumstance of the life of the people, save the complete absence of refined foodstuff and the consequent dependence of the people upon the products of their primitive agriculture and of the native vegetation (supplemented by fish and animal flesh when available).

SUMMARY AND CONCLUSIONS.

Dental caries exists in each of the three groups of New Guinea natives which were studied. Its incidence is, however, much lower than that usually observed among most "civilised" peoples.

The incidence of the disease is different in each of the three villages. It was lowest among the inhabitants of Korovagi (sago—staple diet), next lowest among those of Kavataria (yams and fish) and greatest among those of Pātep II (sweet potato).

The relative incidence of the disease is sometimes different in the two dentitions. Thus in Pātep II the incidence of caries of the deciduous teeth is quite low, while that of the permanent teeth is considerably higher. On the other hand in Kavataria this relationship is reversed.

The incidence of caries of the approximal surfaces of the teeth is very much lower in New Guinea natives than in civilised peoples. The incidence of caries of pits and fissures is also lower in New Guinea natives. The difference between native and civilised peoples is, however, smaller in relation to caries of pits and fissures than in relation to caries of the approximal surfaces.

Differences in the characteristics (*e.g.*, age-distribution, clinical features and surface-incidence) of lesions classified as caries suggest (a) that the disease manifests itself in a number of different forms and (b) that differences in the form of the disease exist not only as between native and civilised peoples but also as between groups of native peoples exposed to dissimilar environments.

It is very desirable, therefore, that we should attempt both to define dental caries more satisfactorily and to describe more accurately the criteria (clinical, histopathological, chemical) necessary for its certain recognition.

The association between the presence or absence of Lactobaccillus and the presence or absence of caries is statistically significant.

Persons with caries who had Lactobacillus showed on the average nearly 50% more (a) carious teeth (standing) and (b) carious tooth-surfaces (on standing teeth) than did those persons with caries who had no Lactobacillus.

The results of observations by some other members of the Survey party have been summarised and discussed.

The main difference between the general diet of the New Guinea people as a whole and that of white people in urbanised societies lies in the complete absence from the former of soft, sweet food made from refined (denatured) ingredients (*e.g.*, white flour and white sugar).

The general nutrition was least satisfactory in Korovagi and most satisfactory in Pātep II and Kavataria; yet the incidence of caries was greatest in Pātep II and lowest in Korovagi.

The average calcium-intake for the population seems to be low by our standards, yet only a few cases of mild rickets were observed (radiological evidence).

On the assumption that the absence of evidence of rickets is evidence in favour of an adequate intake of calcium and of vitamin D and in the light of the fact that there seems to be a deficient intake of calcium in the post-weaning period of early childhood, it appears that the intake of vitamin D is certainly not deficient.

APPENDIX A.

A Short Note on Fluorine in Selected Waters.

Pamela B. Jones.

Samples of drinking water were collected from five villages and analysed for their content of fluorine, calcium, magnesium, and for their permanent hardness. The results are shown in table 39.

TABLE 39
Analyses of Samples of Potable Waters from Five Villages.

Village	Source	Month of collection	Fluorine (p.p.m.)	Calcium (p.p.m.)	Magnesium (p.p.m.)	Hardness as $CaCO_3$ (p.p.m.)
Boytalu	spring	October	0.55	73.5	0.0	240
Busama	spring	August	0.55	6.0	1.0	50
Kavataria	spring	September	0.45	77.2	32.6	340
Korovagi	wall near River Purari	October	0.20	4.5	4.4	60
Pātep II	mountain stream	August	0.40	10.2	4.0	90
,,	,, ,,	August	0.30	11.8	4.0	90

It is now well known that an inverse correlation exists between the fluorine content of the domestic water and the incidence of dental caries. Dean and his associates[99, 100] have shown this relationship for drinking water with a fluorine content ranging from 0.0—3.1 parts per million. Attempts to correlate the incidence of caries in these villages with the fluorine content of the drinking water were therefore made. On the basis of the percentage of carious teeth per village the results for the three villages are shown in table 40.

TABLE 40
Correlation of the Incidence of Caries with the Fluorine Content of Drinking Water.

Village	Fluorine (p.p.m.)	Percentage carious teeth per village
Pātep II	0.35	6.32
Kavataria	0.45	4.51
Korovagi	0.20	2.70

[99]Dean, H. T., Arnold, F. A. and Elvove, E.—Domestic water and dental caries, II, A study of 2,832 white children, aged 12-14 years, of 8 suburban Chicago communities, including Lactobacillus acidophilus studies of 1,761 children, Publ.Hlth.Rep., Wash., 56: 761, 1941.

[100]Dean, H. T., Arnold, F. A. and Elvove, E.—Domestic water and dental caries, V, Additional studies of the relation of fluoride domestic waters to dental caries experience in 4,425 white children, aged 12-14 years, of 13 cities in 4 states, Publ.Hlth.Rep., Wash., 57:1155, 1942.

However, since no records of the missing teeth existed and since no control of variables, such as age, sex, diet, race and climate, was possible, no satisfactory correlation could be made. Notwithstanding the lack of significant correlation between the incidence of caries and the fluorine in the drinking water, these fluorine figures are of interest in that the average figure (0.4 p.p.m.: 6 samples) is distinctly higher than the average figure (0.2 p.p.m.) for a series of waters from New South Wales[75]. Admittedly the number of New Guinea waters analysed is small, but the results indicate that it might be of value to extend the survey to include a greater number of water-supplies.

APPENDIX B.

Observations on the Teeth of Some Natives in the Buang Mountains in New Guinea.

This appendix covers some observations made by one of us (D.A.C.) while with a section of the party proceeding on foot from Pātep II to Busama, south of Lae near the head of the Huon Gulf.

The European Medical Assistant at Mumeng and visiting natives had reported that a large number of people in the Mapos group of villages were affected by dental caries, many more than in Pātep II. As the route to the coast passed through these villages, the opportunity to investigate the reports was taken.

The villages visited were Mapos, Siouga, Bulantim and Wagau, all in the Buang Mountains on the southern side of the Snake River. About 50 men and women from the throng of natives who greeted the party at each place were examined. As time was limited, the examination was rather hurried and was made only to determine whether or not there was a large population of natives with caries. The examination was made with mirror and probe and it is certain that some small cavities were overlooked. In table 41 figures are recorded of the carious and missing teeth only; the number of tooth-surfaces affected was not noted. The second, third and fourth columns in the table show respectively the number of subjects examined in each age-group, the number with caries and the total number of decayed and missing teeth. The ages of the natives were only roughly estimated, as no records were available.

Of the 190 subjects inspected 149 (78%) had one or more missing or carious teeth and the average number of missing and carious teeth for all ages was 5.9 per individual. The corresponding figures for Pātep II are: 136 subjects; 75 (55.2%) subjects with caries; 3.8 missing or carious teeth per person. If the distribution of the population in age-groups is assumed to be similar in the two villages the χ^2 value of 19.97 can be regarded as indicating a significant difference in the prevalence of caries.

The general impression was that the gingival and periodontal conditions were about the same as at Pātep II and that those teeth actually missing had been lost through caries. The teeth had been attacked in all the three usual sites, approximal, occlusal and gingival. It was not possible in the time available to seek reasons for the high incidence of caries in this group of villages (78.4%) as compared with that of Pātep II (55.2%). However, it was noted that the natives had very little contact with Europeans and that their staple food was yam.

This report is admittedly based on a very incomplete examination of the teeth of a relatively small group of natives; nevertheless it is certain that in this group of villages the incidence of dental caries is higher than in the three principal villages visited.

TABLE 41

The Age and Sex Distribution of Natives with Caries in some Villages in the Buang Mountains. [Each number (under villages) represents one native and its magnitude indicates the number of carious and/or missing teeth.]

Approx. age (years)	No. subjects examined	No. subjects with caries	No. carious and/or missing teeth	Village							
				Siouga		Mapos		Bulantim and Lamatim		Wagau	
				male	female	male	female	male	female	male	female
1–5	13	9	41	3	0	0, 0, 2, 5	2, 2	0	—	4, 5	7, 11
6–10	39	29	127	1, 3, 4	3, 5, 7	1, 2, 5, 9	0, 0, 2, 4, 4, 6	0 0, 0, 0, 3, 4, 8	0, 3, 4,	0, 1, 2, 3, 4, 4, 5, 6	0, 0, 7, 8, 9
11–15	47	34	192	2, 2, 4, 4, 5, 8	0, 2, 4, 4, 6, 12	2, 3, 12, 20, 22	0, 2, 4, 5, 7, 9	0, 0, 0, 1, 4, 5, 6	0, 0, 0, 0, 0, 1, 1, 2, 11	0, 0, 3, 3, 4	0, 4, 8
16–29	47	34	259	0	3, 4, 4, 5, 6, 7, 10, 15	2, 3, 4, 8, 10, 13, 28	0, 0, 9, 12, 15	0, 1, 6	0, 0, 0, 1, 3, 3, 4, 14	0, 2, 3, 4	0, 0, 0, 0, 0, 4, 7, 10, 10, 12, 17
30–44	37	36	363	0, 1, 3, 5, 7, 9, 10, 11, 11, 12, 16, 18,	8, 11, 16, 18, 22	20, 25	2, 7, 18, 30	1, 2, 3, 3, 12	6, 15	1, 4, 18	1, 2, 6, 9
45 and over	7	7	151	—	—	16	—	—	26, 30, 30	2, 25	22
Totals	190	149	1133								

APPENDIX C.

ODONTOCLASIA.

During our examination of New Guinea natives we observed a condition similar in some respects to dental caries yet sufficiently dissimilar in others to merit separate mention.

The condition has been observed in two other populations on tropical islands: on Hawaii by Jones *et al.*[101, 102], and on Manus by Kirkpatrick[61]. These authors have given the disease the title of Odontoclasia and use the following criteria to describe it and differentiate it from dental caries.

i. Clinical picture of affected dentine. Both groups of writers describe two distinct types of the disease, distinguished by the way in which the dentine is affected. In one type the dentine is softened, rough and carious in appearance, in the other type it is hard and eburnated and the teeth have sometimes been worn down to their gingival margins, despite the fact that the subjects are children.

ii. Location of lesions. Lesions occur on all surfaces of the teeth, including those which are normally immune to caries, and progress over the surfaces in

[101]Jones, M. R., Larson, M. P. and Pritchard, G. P.—Dental disease in Hawaii, Dent.Cosmos, 72:439, 1930.

[102]Jones, M. R.—Taro and sweet potatoes versus grain foods in relation to health and dental decay in Hawaii, Dent.Cosmos, 76:395, 1934.

broad lines rather than by 'boring into pits and fissures'. Odontoclasia attacks especially the middle third of the incisors.

iii. Incidence. It seems to have been described as endemic only on these two tropical islands and 'is confined almost exclusively to the deciduous teeth'. Kirkpatrick found that its incidence is different in districts where the incidence of typical caries is the same.

iv. Aetiology. This has not been determined. Kirkpatrick considers that the cases he observed may be due to the inability of the mothers to supply sufficient calcium and phosphorus to the foetus. Jones and his co-workers blame mainly the increased consumption of imported grain foods by the native Hawaiians.

It seems that the condition of the deciduous teeth seen by us relatively often in Kavataria but also occasionally in both Pātep II and Korovagi is in several respects similar to that described by the authors mentioned above. A fuller description of the condition is as follows:—

i. *Clinical features of affected dentine.* In Kavataria and Korovagi the lesions were of the 'carious'-dentine type. In Pātep II they were of the hard, smooth, eburnated-dentine type and on first appearance the condition seemed to be associated with an edge-to-edge bite, the crowns of the upper and lower anterior teeth being 'worn down' to the gingival margin. On further examination it was observed that, with the posterior teeth in occlusion, there was a considerable space between the incisal 'surfaces' of the anterior teeth. These 'surfaces' were smooth and slightly convex anterio-posteriorly; the dentine was hard and stained a deep brown with a lighter area representing secondary dentine and in the centre of the 'surface.' Because of the well-formed secondary dentine hardness of the incisal 'surface' the teeth did not appear to have been attacked by caries or to have been broken by injury; rather did they look as if they had been subjected to intensive attrition.

ii. *Location of lesions.* In Kavataria and Korovagi lesions occurred in unusual sites such as the cusps and marginal ridges of teeth and the middle third of the labial (and occasionally also the lingual) surface of the incisors.

iii. *Incidence.* In Kavataria and Korovagi lesions in the deciduous teeth in which the affected dentine had the characteristics of caries were seen much more often than was caries of the permanent teeth.

iv. *Aetiology.* On the island on which the condition seemed commonest imported grain-foods were not eaten at all and the natives were at that time living on locally produced foods. However, it was only two years since the end of the war during three years of which 70,000 servicemen are said to have visited the island and almost certainly gave to the natives some of their food-stuffs, for which the natives in our experience showed a great liking.

However we do not think that the condition is as yet sufficiently well differentiated from true dental caries to be described under a separate name. Ker[103] also has suggested that it should be more thoroughly investigated before being classified as a distinct disease.

In the presentation of the data we have not described the disease separately as such, but the lesions presenting 'carious'-looking dentine have been called

[103]Ker, A. J.—Dental caries; critical study of investigations in the Hawaiian Islands, J.Amer.Dent.Ass., 23:17, 1936.

dental caries and the others showing the eburnated dentine have been excluded from consideration. Additional reasons for this mode of presentation of the data are:—

(a) It seems strange that one process should be able to affect the dentine in two such different ways. It is possible, however, that one may be a later stage or a more slowly progressing form of the other. If this is the case, then in any district where the disease is prevalent one might expect to see both stages or forms and also some which are intermediate. Yet in our experience the two appearances occurred separately in entirely different districts: furthermore, intermediate stages or forms were not seen.

(b) Although it is somewhat uncommon to find carious lesions at sites such as the middle third of the labial surfaces of incisors, nevertheless in civilised children, when they do occur, the condition is described as rampant dental caries.

(c) The aetiology is uncertain and the possible causes appear to be different in each island.

ACKNOWLEDGEMENTS.

We wish to record our gratitude to Professor A. N. Burkitt, Dr. W. N. Benson, Dr. H. O. Lancaster, Staffs of the Departments of Radiography and Photography, United Dental Hospital of Sydney, Mr. H. R. Sullivan and Miss G. Carey.

EXPLANATION OF FIGURES.

3. Odontoma (Pātep II).
4. Supernumerary Upper Right Lateral Incisor (Korovagi).
5. Two Supernumerary Bicuspids, Lower Right (Kavataria).
6. Two Supernumerary Bicuspids, Lower Left. (Same Subject as in Fig. 5.)
7. Congenital Absence of Upper Left Lateral Incisor (Pātep II).
8. Congenital Absence of Upper Left and Right Lateral Incisors. (Same Subject as in Fig. 7.)
9. Congenital Absence of Upper Right Lateral Incisor. (Same Subject as in Fig. 7.)
10. Congenital Absence of Upper Left Second Premolar, Second and Third Molars and Lower Left Third Molar (Pātep II).
11. Congenital Absence of Upper Right Second Premolar and Third Molar, and Lower Right Third Molar. (Same Subject as in Fig. 10.)
12. Impaction of Both Lower Third Molars (Pātep II).
13. Unerupted and Impacted Upper Left Canine (Pātep II).
14. Attrition (Pātep II).
15. Attrition. (Same Subject as in Fig. 14.)
16. Attrition. (Same Subject as in Fig. 14.)
17. Attrition (Pātep II).
18. Attrition (Pātep II).
19. Attrition (Korovagi).
20. Attrition: Complex Direction of Wear.
21. Attrition: Complex Direction of Wear.

22. Normal Occlusion (Korovagi).
23. Normal Occlusion. (Same Subject as in Fig. 22.)
24. Class I Malocclusion, Upper Lateral Incisors in Slight Linguoversion and Retained Deciduous Lateral Incisor Root (Pātep II).
25. Class I Malocclusion. (Same Subject as in Fig. 24.)
26. Class I Malocclusion. (Same Subject as in Fig. 24.)
27. Class I Malocclusion, Upper and Right Central and Lateral Incisors in Linguoversion (Pātep II).
28. Class I Malocclusion, Upper Central Incisors and Right Canine in Linguoversion (Pātep II).
29. Class I Malocclusion, Unilateral Crossed Bite. This was the only example involving more than one tooth (Pātep II).
30. Class I Malocclusion, with Deep Anterior Overbite and Lower Premolar Malposed Lingually (Korovagi).
31. Class I Malocclusion, Deep Anterior Overbite (Pātep II).
32. Class I Malocclusion. (Same Subject as in Fig. 31: Pātep II.)
33. Class I Malocclusion, Lower Left Third Molar Impacted.
34. Class I Malocclusion, with Supernumerary Lateral Incisor (Pātep II).
35. Class I Malocclusion. (Same Subject as in Fig. 34.)
36. Class I Malocclusion, Upper Right Canine rotated 150°; Upper Left Canine unerupted. (Same Subject as in Fig. 13.)
37. Class I Malocclusion. (Same Subject as in Fig. 36.)
38. Class I Malocclusion. (Same Subject as in Fig. 36.)
39. Class II, Division II Malocclusion.
40. Class II, Division II Malocclusion. (Same Subject as in Fig. 39.)
41. Class II, Division II Malocclusion.
42. Bone-loss, Group 2. Small Pocket Distal to Upper Left First Molar.
43. Bone-loss, Group 2, with Occlusal and Approximal Attrition (Pātep II).
44. Bone-loss, Group 2, with Occlusal Attrition.
45. Minimal Bone-loss in Group 3 (Kavataria).
46. Minimal Bone-loss in Group 3. (Same Subject as in Fig. 45.)
47. Bone-loss, Group 3 (Pātep II).
48. Bone-loss, Group 3 (Kavataria).
49. Bone-loss, Group 3 (Kavataria).
50. Black-stained Teeth and Gingival Recession (Kavataria).
51. Black-stained Teeth, Gingival Recession and Calculus (Kavataria).
52. Black-stained Teeth, Gingival Recession and Calculus (Korovagi).
53. Extreme Loss of Supporting Tissue (Kavataria).
54. Retained Root Fragments.
55. Cavities which have apparently started at the Gingival Margin.

The DENTAL JOURNAL of AUSTRALIA
N.S.W.

EDITORIAL DEPARTMENT

THE CONGRESS

Many of our readers will recall with pride and pleasure that the First Australian Dental Congress was held in Sydney in February 1907. The younger members of the profession will be interested to learn that at the time negotiations were commenced, no less than five dental organisations existed in New South Wales.

History records how these have been welded into the one firmly established New South Wales Branch of the Australian Dental Association. Between then and now many problems have been before the profession, but each has been met and solved as growth and development continued, despite the interference of two World Wars.

It was a most significant feature of this First Australian Dental Congress that emphasis was laid on dental education—three important papers were given on dental education and the development of legislative controls on the practice of dentistry. In the sense in which education was discussed it was specifically restricted to the requirements of educational training preliminary to the practice of dentistry.

Dental practice becomes a process which is constantly educational, for there is always something new to be learned where health service is practised. It can, however, degenerate into a monotonous mechanical vocation if the practitioner does not remain on the alert.

In 1907 the leading members of the profession were aware of the need for mental stimulation and the value provided by Congress for the interchange of ideas and experience in the right atmosphere.

Professor Anderson Stuart on that occassion in his address of welcome, stressed that, although legislation had some value as a protective mechanism for the profession, legislation did not make a profession learned any more than Acts of Parliament made men good. He foretold the development of the Faculty of Dentistry and the establishment of a senior degree which in his wisdom he saw as the ultimate of that development.

No doubt he had visions of a fine Dental Hospital and a broad curriculum for the student in dentistry and he was fully apprised of the value of such functions as the Congress would have on the profession.

He counselled caution and steady development, and today the members of the dental profession can be justly proud in the stage of development reached

by dentists in Australia where University education is the pathway to dental practice—ample justification of Anderson Stuart's warning—"Chi va piano va lontano."

The Twelfth Australian Dental Congress, held at a time when rapid advances are being made in preventive dentistry, will have a markedly different complexion from the First Congress.

With the advantage of modern technology a more facile presentation of the wealth of material collated will be possible, and fortunately so, for transport facilities of 1950 ensure that large numbers of practitioners will be in Sydney during August.

Through the generous co-operation of the Senate of the University of Sydney and the Board of Control of the United Dental Hospital and the Lord Mayor of Sydney, the Congress Commission has every confidence that all members will have an ample opportunity of attendance at the various sessions and at the Scientific and Trade Exhibitions.

The profession in Sydney extends a most hearty welcome to colleagues throughout Australia to come to Sydney in August, 1950.

Correspondence

"Anomalies of the Dentition"

Sir,

Your correspondent, Mr. Christy, is certainly entitled to his opinion regarding the value of any articles published in your journal, but it is an entirely different matter how much his opinion is worth. Somewhat the same problem confronted Professor Crew when he wrote his book *Genetics in Relation to Clinical Medicine*, and in regard to it he said, "So it is that the geneticist, eager to share with others the joy of discovery and to display the considerable attractions and possible usefulness of his subject, encounters embarrassment at the start." Some few paragraphs later he says in regard to the average practitioner, "He is concerned with the acquisition of that limited corpus of knowledge and of that small constellation of skills that will enable him to find a place in clinical medicine with its dramatic episodes, its human contacts and its emotions satisfying rewards. He is interested in the individual, not in the species, in the present and not in the future." It is necessary to say in respect to this that I personally have the greatest respect and admiration for the practitioner, who from day to day copes with the many varied and difficult problems confronting him in the exercise of his profession, and that I also envy the dexterity and skill of many. Thus, Mr. Christy is entitled to his opinion, but at the same time he is not entitled to tell untruths when he says in reference to the "Anomalies of the Dentition" that, "In the main they are merely collections of the works of others . . . which are available to us in the libraries."

As regards this article the main theme with which the writer was concerned was to show that the genes affecting the teeth and the jaws resided in the non-homologous part of the X chromosome, and in an autosomal chromosome and that the nature of the gene in the X chromosome was to exert a suppression effect. To do this I published three hitherto unpublished pedigrees and correlated them with pedigrees that had been published previously, and thus was able to procure sufficient evidence for this assertion. I then constructed a tentative chromosome map of the X chromosome and suggested a possible loci for these genes. The value is not so much in placing these genes in the X chromosome, but in placing them in juxtaposition, and thus realize that a mutation of a growth rate gene affecting the jaws can affect the dentition as well and possibly other derivatives of the ectoderm. This is an entirely new presentation of the problem and as such cannot be said to be a collection of the works of others. Further, in doing this I was able to suggest that there were growth rate genes concerned with the persistent infantile form of the frenum labii superioris, a new suggestion, and thus finally to conclude that the successful reduction of the jaw bones and the teeth throughout evolution was due to this co-operation between genes affecting the jaws and the teeth, which again is an original presentation. The photo-

micrographs of the frenum from 40 mm. and 150 mm. embryos, are, I believe, the first presentation of this structure in serial sections, and enable appreciation of the changes occurring during the 40 mm. stage and 150 mm. stage of embryonic life. So that on the whole the main features in this article, both written and illustrated, were original. Certainly references are made to the works of others, for it is only by assimilating these works that further extensions of ideas are possible. It is most distasteful for the writer to make an appraisal of a personal work in this manner, but it is more distasteful to let an untruth remain unchallenged.

This "gamecock," however, is not satisfied by sharpening his spurs on one bird, but he must needs attack two. It seems hardly necessary to point out that Dr. Gabriel's paper, "The Genetic Types of Teeth," is the first attempt to classify teeth on the basis of segregation, and the detailed and arduous observations in a paper of this type cannot be over-appreciated. That Dr. Gabriel and I should disagree on certain points of emphasis, and that this is published, achieves in the end an elucidation of the problem.

Mr. Christy is concerned that the *Journal* does not publish "simple articles concerning problems met with in everyday practice." He would probably be surprised to know that he is utilising the concepts dealt with in these two articles in everyday practice, in much the same manner as the bushman starts a fire by means of friction, and does not realise that he is utilising certain principles of physics. When he chooses the teeth for an edentulous patient, he takes cognisance of the size and general form of the mouth, the complexion of the patient, and thus chooses teeth that are suitable for the patient. That these teeth are suitable is because there is co-operation between genes affecting the teeth, the size and form of the jaws, the colour of the hair, etc.

Mr. Christy is in much the same situation as the practitioner of medicine who, prior to the pathological era, treated inflammation successfully, but was wholly in error as to why the treatment was successful. Who is there to say that the knowledge of the pathology of inflammation was not an advance in medical science? In fact, it would take many pages just to enumerate the many conditions in the science of dentistry, where a knowledge of genetics is essential to fully understand the conditions.

It is indeed gratifying to know that at the head of affairs, in the Association, in the universities of this country, are men who see that such "utterances" do reach print, and not as the savage "Me no savvy—me no likey, by crikey," Mr. Christy.

Yours faithfully,

C. J. GRIFFIN.

9 Parkview Road, Manly.
February, 1950.

"Wax Patterns"

Sir,

There is something inexplicable in the casual attitude that some practitioners adopt towards the fate of their painstakingly obtained patterns. Indeed, so careful are they that frequently they obtain a spare pattern. Yet both of these patterns are in the main subjected to conditions that only some invulnerable material could tolerate. A lot has been written on the behaviour of gold alloys and investment materials; in contrast, however, little has been said about the weakest link in the chain—the wax pattern. It is known that wax, when subjected to softening and subsequent pressure, tends to return to its original shape over a period of time although the temperature remains constant. Consequently, it is logical to invest immediately, then attend to the temporary dressing. The patient's immediate comfort is of little moment when compared with the accuracy of the restoration, which should be the first consideration.

Train your assistant to set up the investing apparatus, even to the asbestos lining and the measurement of the powder and water. Little time is taken to invest a pattern. When it is invested you may cast it a week later if desired. Far better to send to your mechanic the invested inlay pattern if send it you must! Why spend time at the chairside endeavouring to obtain a first-class pattern, then to subject it to all the hazards that go to produce a dismal failure?

Yours faithfully,

N. WALTER KESTEL.

Park Street, Sydney.
February, 1950.

News and Notes

NORTHERN SUBURBS DENTAL GROUP

Members are notified that the Annual Sports Day of the Northern Suburbs Dental Group will be held at the Killara Golf Club on Thursday, 20th April, 1950. Golf and bowls competitions are planned.

Return your completed entry form as soon as possible and you will earn the Committee's appreciation.

DENTAL JOURNALS REQUIRED

A request has been made from the Fisher Library, University of Sydney, for copies of the New Zealand Journal of Dentistry, Volume 44, Nos. 215 and 216, 1948. Any member who has a copy of these would he communicate with the Secretary?

WESTERN SUBURBS DENTAL GROUP

Members are notified that the Annual Sports Day of the Western Suburbs Dental Group will be held at Concord Golf Club on Thursday, 11th May, 1950. Competitions in golf, bowls and tennis will be held. Also, the Third Annual Ball of the Group will be held at Petersham Town Hall on Thusday, 1st June, 1950.

University of Toronto, Faculty of Dentistry.

GRADUATE COURSES IN DENTISTRY
ORTHODONTICS

Applications will be received up to 1st March (for 1950 this date will be extended) for the graduate course in Orthodontics at the University of Toronto. The course commences on 1st September and continues for a period of seventeen months. Enrolment is limited to six graduates of approved dental schools. The applicants must possess satisfactory scholastic standing acceptable for enrolment for the Master of Science (Dent.) Degree in the School of Graduate Studies of the University of Toronto. This course is under the direction of Dr. Robert E. Moyers, Professor and Head of the Department of Orthodontics.

For further information and application forms, address all inquiries to: The Dean, Faculty of Dentistry, University of Toronto, 230 College Street, Toronto, Ontario, Canada.

Association Activities

AUSTRALIAN DENTAL ASSOCIATION
NEW SOUTH WALES

Extract from Minutes of Meeting of Executive Committee held in the Council Room, B.M.A. House, 135-137 Macquarie Street, Sydney, on Monday, 23rd January, 1950, at 7.30 p.m.

Present: Dr. E. R. Magnus, President, in the Chair; Dr. F. E. Helmore, Vice-President; Dr. R. M. Cloutier, Honorary Treasurer; Mr. H. M. Finnie, Mr. W. A. Grainger, Mr. R. G. Leeder, Mr. R. Y. Norton, Mr. F. R. Reid, Mr. J. W. Skinner, Mr. H. R. Sullivan, Mr. Ralph Tompson, Mr. L. Mackenzie, Blue Mountains Division; Mr. C. D. Reynolds, Newcastle and Hunter River District Division; Dr. J. D. Oddy, South Coast Division; Dr. A. G. Rowell, Western Division.

Apologies: Dr. A. G. H. Lawes, Vice-President; Mr. E. H. Bastian, Dr. J. V. Hall Best, Mr. N. E. Edney, Mr. R. Krauss, Dr. J. D. Benson.

In attendance: Mr. Robert Harris, Secretary.

Welcome to Mr. Reynolds: The President welcomed to the meeting Mr. C. D. Reynolds, of the Newcastle and Hunter River District Division.

Business Arising from Minutes:

Training Scheme for Dental Assistants: The Secretary reported that he had interviewed two representatives from the Dental Assistants' Association and, after discussion, it was agreed that a course of training should be deferred until proper facilities were available.

It was resolved that the Secretary's report be received.

Kempsey Flood Relief: It was reported that a cheque for £5/5/- (sterling) had been received from the British Dental Association, and that some replies had been received from the Victorian Branch members in response to that branch's appeal.

New Graduates—Positions Available: The Secretary reported that, in reply to his request for information relative to positions for new graduates, he had received a reply from the South Coast Division regarding a vacancy at Eden which had since been referred to several graduates, a reply from the St. George District Dental Association suggesting three possibilities, and a reply from the Far North Division indicating that there were no positions at the present time.

It was resolved that this report be received.

Federal Office:

Conference with Minister for Health re National Dental Health: Letter dated 22nd December, 1949, from the Federal Office confirming the telegram sent relative to a conference with the Minister for Health was read, and the Secretary reported that immediately on receipt of this a reply had been despatched indicating that the New South Wales Branch would be prepared to attend a conference early in February with the Minister, preferably at Sydney, at which the President and Mr. Edney would attend as delegates.

It was resolved (1) That this report be received, (2) That the President and Mr. Edney act as delegates, with the Secretary in attendance, at the conference with the Minister for Health.

Working Party's Report and Statement by State President: It was reported that the Working Party's Report had been circulated to the State Branches seeking their comments. Replies from the Queensland, West Australian, Tasmanian and South Australian Branches dated 13th, 14th, 19th and 23rd December, 1949, respectively, were read.

A statement by the President, Dr. Magnus, setting out the New South Wales Branch's opinion relative to any proposed National Dental Health Scheme was circulated to the members present and considered, and the President stated that it would be preferable for the Federal Council to meet prior to the conference with the Minister in order to discuss differences of opinion between the States and arrange for points not agreed upon to be placed before the Minister.

It was resolved that the President's statement be forwarded to the Federal Office as the opinion of this State Branch, and that a request be made for a meeting of the Federal Council to be held prior to any conference with the Minister for Health.

Federal Constitution: The Secretary reported that the whole question of the Federal Constitution had been referred to the Association's solicitor, Mr. Utz.

Congress Commission: The Secretary reported that the Congress Executive Com-

mittee had reserved the Lower Town Hall for the screening of films and scientific and trade exhibits with an aim to have two public sessions, and that Dr. W. Terrell, of U.S.A., had agreed to attend Congress.

Reports from Committees:

Dental Health Education: The Chairman of the Dental Health Education Committee, Mr. Tompson, reported that the Education Department had intimated that the film "Talking of Teeth" is in great demand, and that a review of it had appeared in the *Government Gazette*, a copy of which was to be sent to the office for information.

Divisions: The Secretary reported that in reply to his enquiry to the date of the Delegates from Divisions Meeting, the Far North Division had stated that it had no particular preference and the South Coast Division had suggested that the meeting be held in June.

Survey of Fees: The Convenor of the Survey of Fees Committee, Mr. Skinner, reported that the information contained in the replies to the questionnaire was being collated, but as this involved an immense amount of work a final report would not be ready before about March of this year.

Membership: The Chairman of the Membership Committee, Dr. Helmore, reported that the committee had considered several matters and made recommendations, which he read to the meeting. It was agreed that at the bottom of the notice to students there should be a form of application for Student Membership.

It was resolved that the recommendations of the Membership Committee, as follows, be adopted: (1) That the term "Student Associate" be applied to Fourth-year Students who pay a fee to the Association for special facilities. (2) That Fourth-year Students be addressed in the first week of the Vacation Term by the Secretary; that the President be requested to be present to introduce the Secretary to the students, and that the members of the Membership Committee be present also. (3) That this lecture be repeated in the first week of Lent Term to students who are repeating fourth-year and students who are successful in the third-year deferred examinations. (4) That a notice be handed to students, giving details of the benefits to be derived from becoming a Student Associate.

New Graduates: It was resolved that the following recommendation of the Membership Committee be adopted: That a letter signed by the President be sent to all new graduates congratulating them upon their graduation and inviting them to become members of the Association and setting out the terms in accordance with the Articles of Association.

Restricted Membership Applications: Dr. Helmore reported that Membership Committee had also considered applications for restricted membership from members practising in special circumstances. The Membership Committee had decided that these matters should be referred to the Executive Committee as Article 6A (a) and 6A (d) of the Articles of Association do not appear to make restricted membership available to these applicants.

It was resolved that this matter be referred to the Committee of the Honorary Officers.

Honorary Member—Dr. E. C. Gates: The President reminded the Executive that at the Annual General Meeting, Honorary Members had been elected as in previous years. However, in view of the many years' service Dr. E. C. Gates had rendered to the profession both as a member of the Faculty of Dentistry and of the staff of the Dental Hospital, the Association would, he felt sure, agree to honour him with election as an Honorary Member.

It was resolved that it be recommended to the first General Meeting of the Association that Dr. E. C. Gates be elected an Honorary Member.

Syllabus: The Chairman of the Syllabus Committee, Mr. Skinner, reported that as Dr. Bradlaw, of Sutherland Dental School, Newcastle-on-Tyne, would be visiting Sydney, he had asked the Secretary to invite him to address a General Meeting.

Sports: The Chairman of the Sports Committee, Mr. Reid, reported that his committee had agreed to take over the cricket activities of the Association, which in the past had been conducted by individual members. This year, as usual, the cricketers selected for the B.M.A. v. A.D.A. match to be held at the Sydney Cricket Ground on 8th February, 1950, would meet the cost of the match, but in the future it was intended to approach the B.M.A. with a view to the costs being borne alternately or in equal shares by those associations. The Sports Committee would appreciate members of the executive attending this cricket match.

Membership:

New Member: It was resolved that Mr. Thomas Laidlaw Gregan, whose application was in order and who had paid the requisite subscription, be admitted to membership of this State Branch as from 23rd January, 1950.

Restricted: It was resolved that the following members of this State Branch be granted restricted membership:—Dobson, Charles Thornton; Golby, Charles Henry; Heaphy, George Arthur; Morris, Archibald Clarence; Neave, Bevan Walke; Twartz, Victor Bernard Paul.

Resignations: It was resolved that the following resignations from membership of this State Branch as from 31st December, 1949, be accepted with regret:—Dansey, George F. S.; Fahl, C. W.; Wilkinson, R. T.; Carr, S.

Deceased: It was noted with regret that Mr. Thomas Combe, of Rockdale, had died on 29th December, 1949.

Correspondence:

Honorary Members: Letters from Mrs. Barr, Mr. McKegg, the President of the New Zealand Dental Association, and Dr. P. C. Charlton conveying their thanks for appointment as Honorary Members of the Association, were received.

Victorian Member Visiting Sydney: Letter dated 12th December, 1949, from the Victorian Branch requesting that an invitation be extended to Surgeon-Lieut. (D) A. G. Robertson, a member of that State Branch, to attend meetings while he is stationed in Sydney, was read and it was agreed that he should be invited to attend meetings.

General Business:

Dental Mechanics' Log of Claims: The Secretary reported that a meeting of the Dental Mechanics' Conciliation Committee called for 23rd December, 1949, was postponed until 1st February, 1950, when a conference at the Trades Hall would be held with all parties in order to determine what clauses of the log of claims could be agreed upon.

Industrial Arbitration Committee: It was resolved that the alternate members of the Dental Mechanics' Conciliation Committee, Messrs. Edney, Skinner and Wilson, be appointed a committee to deal with industrial matters and that Mr. Edney be appointed chairman of this committee.

Lecture at Goulburn: It was resolved that approval be given to Mr. N. D. Martin to lecture to the Southern Tablelands Division at Goulburn on 25th February, 1950.

Selection of Lecturers for Divisions: In answer to an enquiry as to the method of selection of lecturers for Divisions, the President stated that there was no particular method but that when Divisional Secretaries write asking for a particular person he is requested to go, or if they ask for a lecturer in a particular subject the Secretary, after consultation with the President, asks a suitable member.

It was resolved that the selection of lecturers be dealt with by the Syllabus Committee in collaboration with the Chairman of Divisions.

New Books and Publications

DENTISTRY IN PUBLIC HEALTH

Edited by W. J. Pelton and J. M. Wisan.

W. B. Saunders Company, Philadelphia and London, 1949.
By courtesy of W. Ramsay (Surgical) Pty. Ltd., Melbourne. *Price,* 38/6.

Without any hesitation it can be said that this is a most timely publication for all persons interested in the vast problems involved in public health dentistry. The book consists of 17 chapters, each written by a specialist in a particular field, and is an intense compilation of data and methods of procedure employed by the various agencies working in the field of public health dentistry in America. The fact that the book deals *in toto* with American conditions does not in any way detract from its value in other parts of the world.

The theme develops on broad lines and shows how the Government instrumentalities both local and state and national instrumentalities can all be organised to work for the benefit of implementing a form of Dental Health Service.

The work carried out early in the history of American Dental Association in regard to its dental health measures is outlined and its impact studied on the public generally. It is of interest to see how small beginnings of this work have developed into such an integrated and carefully planned system under which a large variety of material has been prepared and is constantly being demonstrated for the benefit of dental health education.

The significance of carefully planned programmes of dental treatment in the form of services assisted by Government instrumentalities is demonstrated and the part the private practitioner can play in such a programme.

The economic aspects of the dental health problems are discussed in great detail and a most valuable chapter has been set up on the biometrical analyssi of any type of survey or dental health programme.

The question of nutrition and diet in relation to dental health laboratory test of caries activity, the impact of fluoride therapy, both in regard to water-borne fluoride and experimental addition to domestic supplies and the control aspects of this work are dealt with by two of the outstanding men in America of the present day.

The vast administrative problems in dental health are surveyed and related to community health problems and so through state instrumentalities to the national over-all programme.

To the research worker interested in the impact of new methods on the community as a whole and not to restricted groups, many sections of the work can be commended, and it is a fitting conclusion that the last chapter has been written by the present Secretary of the American Dental Association, who has briefly touched upon the work of the Association and that of other organisations interested in the problem of public health, particularly certain private foundations, whose benefactions have enabled large numbers of children to receive a high standard of dental treatment.

There is another field of personnel to whom the book can be fully recommended and that is the new graduate embarking on the field of private practice, or as a member of a Government health service. Both will learn much of value in regard to the impact of dentistry upon the public and also the impact of various age groups and their particular requirements by the profession.—R.H.

REVIEW OF DENTISTRY

Edited by James T. Ginn.

C. V. Mosby Co., U.S.A., 1949.

By courtesy of W. Ramsay (Surgical) Pty. Ltd., Melbourne. *Price*, 43/-

The whole work is based on the question and answer principle and has been divided up into various chapters for each section. No doubt there are many

people who like this type of presentation and for short brief analyses of certain sections of the work it might be quite useful. The index no doubt helps to reduce the difficulties which the reader may encounter if he has no question formed in his mind.—R.H.

THE ARTICULATOR

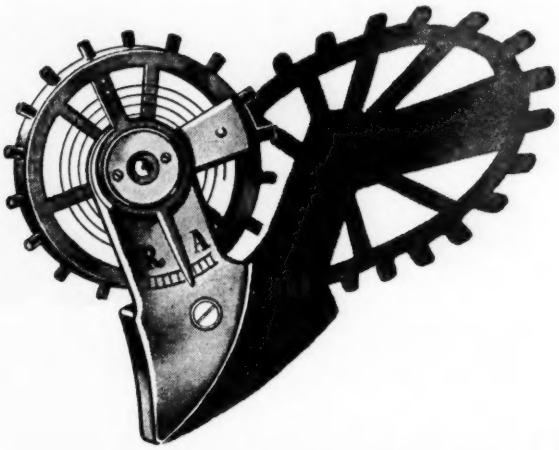
Published by the Dental Undergraduates Association of the University of Sydney.

Maintains the high standard noted in the previous publication. The form of the Journal has naturally been designed to cope with their requirements, and it is interesting to see the way in which the Student Body has coped with the problem of the large numbers of students in the final year.

The literary standard has reached the same general excellence of previous years and a valuable talk has been printed which was given by Professor Arnott, Dean of the Faculty of Dentistry to the students and it is hoped that much of the wisdom contained therein will be remembered by them during the whole of their professional career.

There is an excellently prepared paper on "The Role of Salivary Enzymes in the Process of Dental Caries" by one of the Senior Students, and it is put forward as a suggestion that in the future further contributions be printed from students rather than depending upon the graduates. This is no criticism of the very informative article by Mr. N. D. Martin, but it would be preferable to have 100 per cent. production from the students.

We look forward to seeing the next issue of the "Articulator" with keen anticipation.—R.H.



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